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DATA PROCESSING and TRANSFER

OAST Summer Workshop

OAST ODU 1975

National Aeronautics and Space Administration
Office of Aeronautics and Space Technology and Old Dominion University

Vol I of X

NOTICE

The results of the OAST Space Technology Workshop which was held at Madison College, Harrisonburg, Virginia, August 3 - 15, 1975 are contained in the following reports:

EXECUTIVE SUMMARY

VOL I	DATA PROCESSING AND TRANSFER
VOL II	SENSING AND DATA ACQUISITION
VOL III	NAVIGATION, GUIDANCE, AND CONTROL
VOL IV	POWER
VOL V	PROPULSION
VOL VI	STRUCTURE AND DYNAMICS
VOL VII	MATERIALS
VOL VIII	THERMAL CONTROL
VOL IX	ENTRY
VOL X	BASIC RESEARCH
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NASA

Office of Aeronautics and Space Technology

Summer Workshop

August 3 through 16, 1975

Conducted at Madison College, Harrisonburg, Virginia

Final Report

DATA PROCESSING AND TRANSFER PANEL

Volume I of XI

OAST Space Technology Workshop

DATA PROCESSING AND TRANSFER PANEL

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I. INTRODUCTION

A. Purpose and Scope

This report sets forth the context and results of the Data Processing and Transfer portion of the NASA OAST Summer Workshop, held at Madison College, August 3-16, 1975. The workshop was tasked with translating user-community needs into technology program requirements and identifying areas in which space flight experiments could significantly improve the prospects for satisfying those requirements. In the performance of its duties, the Data Processing and Transfer Group considered all of the inputs provided by the user community. These inputs, as well as applicable items from Outlook for Space, are detailed in SECTION II, WORKSHOP INPUTS. The scope of the various inputs led to the formulation of two broadly applicable focusing requirements, which are discussed in SECTION III, MAJOR PROGRAM THRUSTS. The specific technology programs derived by the group are contained in SECTION IV, TECHNOLOGY REQUIREMENTS. SECTION V, FLIGHT EXPERIMENTS, documents areas in which flight experiments will significantly advance the accomplishment of the desired technology goals. These experiments are representative, rather than exhaustive, and may be modified as technologies mature or interfaces with other disciplines, such as Sensors and Data Acquisition, are worked in greater detail.

II. WORKSHOP INPUTS

A. Background

The objectives of this Workshop were identification and dccumentation of a comprehensive technology development program which would fulfill NASA requirements through the year 2000. This program was to include definition of specific tasks down to component level and identification of flight experiments which could measurably aid in the accomplishment of the development program. The criteria for selection of technology candidates were embodied in "1975 NASA OAST SUMMER WORKSHOP OVERVIEW REPORT," the "Outlook for Space" draft report and "Forecast of Space Technology". The first of these reports contained a compilation of requirements from the "User Community", which was composed of the major NASA offices (e.g., OA, OSS, OMSF, and OTDA). The latter two reports were the result of a year-long NASA-wide study to define and suggest options for future NASA direction. The initial two days of the Workshop were devoted to presentations to the Working Groups by Users and Outlook participants explaining the requirements.

B. Users

The initial and primary guiding user "drivers" for the Data Processing and Transfer Group came from material supplied by OA, OSS, OMSF and OTDA, which showed a compilation of envisioned technology needs for the 1980-2000 time span. These depictions were supplemented to the degree practical, with interface meetings at the Workshop between individuals of the Technology User Group and the Data Processing and Transfer Group.

At the beginning of the Workshop, material was supplied from each of the four offices. That which was perceived as being reasonably directly related to the data function was used as a source of drivers for the Data Processing Transfer Group. The material from OA centered in the basic areas of communications, earth observations, and earth and ocean physics. OSS needs centered in the basic areas of astronomy and planetary communications. The inputs from OMSF concerning improvements in image enhancement, narrow band TV and reduced BW for real-time TV. OTDA needs related largely to deep space data systems. All of these inputs combined to form an ensemble which covers a rather wide spectrum of data related technologies. A tabulation of the user-community inputs, by Office, is contained in Table II-1. A separate listing, with additional technology areas, was supplied by the Technology User Group. It is outlined in Table II-2.

C. Outlook for Space

During the past year, a wide-ranging study of possibilities for civilian space activities during the period 1980-2000 was conducted by a special group established by Dr. James C. Fletcher. Two major products of this study were made available in draft form to group participants at the opening of the workshop. The "Main Report" contains description and rationale supporting twelve major themes for Earth-oriented and extraterrestrial activities. These are further broken down into 125 objectives and approximately 250 representative systems that will contribute to meeting the objectives. The relationship of the themes and objectives to rational interests is explored in depth in this volume. The second volume, "A Forecast of Space Technology", contains predictions of technological capabilities that will be available from 1980 to 2000 that will support the objectives. This material was used during the workshop sessions to characterize present system or subsystem functional capabilities and to establish likely or representative requirements during the years when the STS is operational.

Most of the objectives and systems identified in the course of the Outlook for Space study were not examined in sufficient depth by OFS participants to enable reliable performance requirements to be defined; hence, few specifications of needed capabilities similar to the "user requirements" discussed above can be derived from the "Main Report" or from "A Forecast of Space Technology". During the forecasting effort, however, an attempt was made to identify broad areas of technology that deserved special emphasis in NASA research and development planning. The selection criteria were 1) that the candidates should require full NASA commitment and support for significant advancement, and 2) that they can be expected to have a great impact on future objectives. Those areas of "preparedness technology" that relate directly or indirectly to data processing and transfer are listed in Table II-3.

It will be seen that aspects of all of these items are addressed in the discussion of program thrusts immediately following, and in the technology requirements included later in the report.

USER COMMUNITY INPUTS

OA — COMMUNICATIONS — TELEPHONY, TRUNKING AND BROASCASTING

-CHANNEL AND BEAM ASSIGNMENTS

-LIGHT WEIGHT TRANSPONDERS

-INTERSATELLITE COMMUNICATION RELAY

-LOW COST GROUND STATION TECHNOLOGY

-HIGH BAND COMMUNICATION TECHNOLOGY

EARTH AND OCEAN PHYSICS

-ONBOARD PROCESSING FOR 100 MBPS IMAGERY

-GROUND STORAGE SYSTEMS OF IMAGES

-IMPROVED MICROWAVE MEASUREMENT TECHNIQUES

EARTH OBSERVATIONS

-ONE GIGABIT PER SECOND DATA SYSTEMS

-IMPROVED CAL TECHNIQUES FOR HIGH RATE SENSORS

-FILTERS FOR SYNTHETIC APERTURE RADAR

Table II-1A

USER COMMUNITY INPUTS—CONTINUED

OMSF —	IMPROVED REAL-TIME IMAGE ENHANCEMENT
	HIGH QUALITY TV OVER LOW GRADE LINES (REMOTE HEALTH CARE)
	BW COMPRESSION FOR REAL-TIME TV
OSS —	PHYSICS AND ASTRONOMY
	-HIGH DENSITY, LOW POWER PROCESSING AND STORAGE
	-LONG LIFE SELF-REPAIRING SPACECRAFT SYSTEMS
	-IMPROVED DATA HANDLING AND TRANSMISSION SYSTEMS
OTDA —	HIGH GAIN STEERABLE SPACECRAFT ANTENNA (FOR DEEP SPACE)
	X-BAND TRANSPONDER (FOR DEEP SPACE)
	K-BAND DOWNLINK (FOR DEEP SPACE)
	10^{15} MASS MEMORY

Table II-1B

TABLE II-2

Technology User Group Inputs

To

Data Processing & Transfer Group

1975 OAST WORKSHOP

ITEM	FUNCTIONAL DESCRIPTION
1.	Domestic Communications -- Electronic Mail, Medical, Educational (Outlook For Space - 051)
2.	Intercontinental Communications (Outlook For Space - 052)
3.	Personal Communications (Outlook For Space - 053)
4.	Communication/Navigation (Outlook For Space - 034)
5.	Hazard Warning (Outlook For Space - 034)
6.	Earth & Planetary Reentry Communications
7.	Microwave Power Transmission
8.	High Throughput Parallel Processor
9.	Low Cost Direct Readout User Data Station
10.	Event Detection
11.	Electronic Components (e.g., High Temp. & Pressure)
12.	High Density Data Distribution
13.	Self-Diagnosing & Correcting Electronic Systems

OUTLOOK FOR SPACE TECHNOLOGY INPUTS

END-TO-END INFORMATION MANAGEMENT

DISTRIBUTED PROCESSING

MASS STORAGE

SOFTWARE PRODUCTION

INFORMATION EXTRACTION AND REPRESENTATION

LARGE ANTENNA APERTURE

SMALL ELEMENT ARRAY

LARGE SCALE INTEGRATED CIRCUITS AND MICROPROCESSORS

SEMICONDUCTOR MASS MEMORIES

Table II-3

III. MAJOR PROGRAM THRUSTS

A. Origin

Examination of workshop inputs revealed a proliferation of flight missions and a large increase in raw data, resulting both from the increased mission model and higher data rate sensors. It is evident that NASA will be unable to fulfill its destiny while continuing to function in traditional ways. Specifically, NASA will be unable to use Shuttle effectively if it continues to implement a unique electronic system with each payload or if it does not break the data processing and transfer log-jam built up in the limited science collection activities of past programs. Recognition of these facts led the Data Processing and Transfer Group to identify two major thrusts as focusing drivers for proposed technology. These were:

1. 1000:1 improvement in information handling capacity.
2. 10:1 reduction in program life-cycle costs.

These two major thrusts are defined and discussed in the following paragraphs. If these goals are pursued vigorously, they appear achievable and they should greatly ameliorate the growing pains that are inevitable in the development of a Shuttle-saturated traffic model.

B. Information Handling Major Thrust

One of the major thrusts identified by the Working Group was a cost-effective thousand-fold increase in NASA end-to-end data handling capacity by 1990. The consensus of the Data Processing and Transfer Working Group was that this major thrust should be achieved through a balanced development of technologies in data processing (both spacecraft and ground based) and data communications and transfer.

Advancement of the technology to perform extensive data processing aboard the spacecraft offers both the greatest challenge and the greatest potential payoff in achieving the goal of this major thrust. Opportunities for processing data onboard spacecraft include, but are not limited to, the following: (1) preprocessing data from sensors via a predetermined invariant transformation algorithms, which reduces the sensor's data rate; (2) automating calibration of sensor data in real time to avoid the transfer of the calibration data via the down link; (3) interactive control of sensor operations either via ground command or onboard systems, which would permit collecting and transferring sensor data only when the desired conditions exist; (4) onboard man interactive recognition processing of high data rate earth resources type data; (5) onboard formatting of data to reduce the time delays and processing costs on the ground. All of these onboard data processing systems result in an increase in the information content of the data transferred via the down link and therefore contribute greatly towards increasing the end-to-end information handling capability. Further improvement in the information handling capability can be achieved by providing data to users on high density digital tape, with a minimum of ground processing, and the increased use of high speed parallel processors rather than general purpose computers.

The other and no less important aspect of this major thrust is advancing the development of higher capacity data links. Even with improvements in the information content brought about by on-board data processing, it was the consensus of the working group that the requirements for data communications will far exceed present capabilities. Technology developments will be required in wide bandwidth, high data rate communication links such as microwaves, millimeter wave and optical data communications systems and the development of signal processing technologies to utilize more effectively the bandwidth available in these communication links.

C. Life Cycle Cost

With the advent of the Space Transportation System during the 1980's, programs and experiments will expand, and reduction of cost per vehicle and flight will become increasingly important. For aircraft and space vehicles, electronics is becoming more dominant as a cost driver in development, acquisition and ownership. It is illusory to think that the cost of commercial devices and equipment such as calculators and digital watches portend an era of cheap electronics for space vehicles and payloads, if other development programs are not undertaken. This is true because of one-of-a-kind experiments, the singular environment, and the costs of software connected with space missions. To design for minimum cost it is imperative that the whole life cycle of the equipment and system operation be considered from end-to-end. This approach has not been popular since it is far easier and less subject to controversy to buy on the single criterion of acquisition cost from the lowest bidder.

This major thrust has been developed on the basis of a desired 10:1 reduction of life cycle cost of electronics and includes the following major areas of accomplishment and approach:

a. Software

1. Modular, reusable, and automatically or computer generated

2. Easily maintained and modified

3. Eventually hard-wired and therefore producible by physical processes rather than human programmers

b. Modular Architecture

1. A standard, and therefore less expensive, core data processing and distribution system that handles any sensor data or change without rewiring or redevelopment

2. Easily expandable or contractable, but still standard for any vehicle or experiment

3. Based on a concept of distributed, standard microprocessors and memory elements, and therefore more reliable and less expensive than a massive central processing unit.

4. Built-in test equipment (BITE) and fault location

5. Based on standard data formats and wide band multiplexing to share lightweight wiring or transfer mechanisms

c. Standard Electronic Modules

1. Use few, highly controlled, reliable, producable, standard digital parts for system fabrication. Make breadboards flyable, thereby reducing cost of development and acquisition.

2. Standard form, fit, and function allowing replacement parts to be procured during different technology eras and still be low cost.

3. With proper software and BITE, a maintenance concept for onboard as well as ground support, with 15 minutes mean-time-to-repair using semiskilled personnel.

d. Fault Tolerant System Design

1. Since components cannot be perfect, and software and data transfer has errors, mission accomplishment depends on system design concepts and theories that allow systems to continue to operate under these imperfect conditions.

2. Graceful degradation rather than catastrophic failure allows online repair, and therefore mission continuations, if proper modular architecture, standard electronic modules and maintenance concepts are employed.

For these items additively to produce the desired 10:1 cost improvement, a program management structure and firm management control of space electronics and software will have to be instituted.

D. Supporting Technology

As the Working Group continued its deliberations and analytical activities, several additional areas of technology too broad for inclusion in one of the major thrusts, or most relevant to another Woring Group area of concern, were identified. To avoid loss of identity, these topics have been grouped under a heading of Supporting Technology and discussed in greater detail below.

1. Failure Physics and Microelectronics Technology

Key factors in achieving greater data-handling capabilities and reducing life-cycle costs are the performance characteristics and reliability of the electronic data-processing subsystems. Because of their importance, these factors are an underlying concern in all military and aerospace electronic system developments, and in the manufacture of some consumer products as well. The driving influence of military and industrial applications is so high that many advances in microelectronics will take place with or without NASA contributions or involvement. Other advances, however, especially those related to long-term reliability under high radiation or at extreme temperatures, may depend largely upon NASA initiative.

The major components of system reliability are organization and component reliability. Ultimately, it is hoped, there will be sufficient understanding of how nature achieves reliable performance from an assembly of imperfect parts so that more emphasis can be placed on organization than on parts reliability in system design. However, studies devoted to the search for such principles are in their infancy, and thus the characteristics of the individual components must be given their proper share of attention.

NASA's requirements for long-term reliability under a variety of environmental stresses arise primarily from the planetary program (although all other programs should benefit from knowledge of how to counteract the effects of radiation, temperature, and chemical contamination). Since these requirements generally far exceed those placed by military and commercial users, who constitute the bulk of the market, NASA's ability to effect changes in manufacturing practices is small, and it must pay a premium to induce the supplier to produce products that meet NASA specifications. In negotiations with industry to secure deviations from normal practices, it is important that parts experts have a good understanding of what physical device characteristics are important and what processing and assembly practices will yield them. Such understanding is likely to be achieved only if NASA maintains a strong and vigorous research and development effort with these objectives:

1) Ascertain the basic physical mechanism that cause failures in the electronic structures and systems produced by the microelectronics industry.

2) Develop physical models of these mechanisms that enable life-time projections to be made, within a range of uncertainty, given defined and measureable initial conditions.

3) Develop processing specifications and requirements that will enable NASA reliability requirements to be met in parts procurement.

4) Obtain a knowledge of future technologists that will enable them to be adopted when industry, for reasons beyond NASA's control, abandons the older ones.

Along with the above research activities, other efforts must be pursued to find more self-reliant, fault-tolerant organizations, and to develop shielding and environmental control methods that may enable military or commercial-grade components to be used in NASA experiments and vehicles. Of equal importance is perceptive and informed management to ensure that the knowledge gained through successful research and development is properly applied in agency procurements.

In the past, a variety of approaches more empirical than these advocated here have been tried by the Navy, the Air Force, and by NASA, usually with the goal of determining the effect of processing on radiation-hardened devices. The results of these efforts have been "recipes" that have been applicable only at the facilities where they were developed, and that generally have been non-transferrable. A more basic approach is needed which attempts to solve difficult and important problems by understanding them.

2. Information and Computer Science

The computer is the symbol for information processing. In twenty-five years, starting from a laboratory curiosity, it has become the focus of a multibillion dollar industry that is still rapidly growing.

While the computer can be regarded as a tool that serves human information processing needs, it is such a complex and powerful tool that its development has spawned new areas of basic studies. Since the aim of these studies is to create organized bodies of knowledge, they can legitimately be called sciences.

It is to be expected that advances in information and computer science, and in their engineering applications, would underlie most of the technology advances projected by the Data Processing and Transfer Group. Similar advances, however, are mandatory for other technologies that depend upon the computer as a tool for use in development or as an operational element of systems. So widespread are the uses of computer systems within NASA that there is a danger of much duplication of effort and reworking of already plowed fields as individuals attempt to improve and understand the computer as a tool while they apply it to their own purposes.

It is essential that, as an agency whose primary role is the acquisition and dissemination of new information about the earth and space, NASA recognizes the functions of information management, as performed by computers and related machines, as subjects of study whose pursuit demands careful planning and review. A wide spectrum of activities should be recognized and supported, ranging from basic research in carefully selected fields of information and computer science to cost and benefit accounting. Data management activities must be understood and coordinated in relation to a carefully considered agency philosophy and perspective. Only by these measures, which place computer-related research, development, and management activities within a coherent framework, is NASA likely to give them purpose and direction, raise the probability of useful and valuable outcome, and to reduce the rate of increase, if not the total, of the expenditures associated with the use of the computer, its most productive and pervasive tool.

3. Transfer of Space Solar Power by Microwaves

Both Outlook for Space and the Office of Manned Space Flight indicated high interest in a program to develop space solar power into an economically viable source of terrestrial energy. The envisioned system would use solar cells to convert incident solar power into direct current power. This power would then be converted to microwaves focused on a relatively small terrestrial spot where it would be reconverted to direct current and fed into the power grid. Output power levels are projected at 5,000 megawatts. A microwave system such as this would not be a simple task and would require major developments, beginning in the immediate future. However, the requirement does not stem from either of the two major thrusts discussed. Rather it is supportive of a major thrust that could be identified in the energy realm.

IV. TECHNOLOGY REQUIREMENTS

A. Discussion

It is clear that all space derived data must be brought down to earth and put into a form that man can understand. Further, implicit in the terrestrial "Outlook for Space" themes is the need for large increases in the amount of information required to implement those themes. For instance, a global food and forestry management capability will require a large step increase in data rates over the present Landsat series, because the resolution must be higher, the spectral signatures must be more detailed, and the frequency of observation must be increased. It is estimated that during its lifetime, Landsat I returned to earth 40 times the total number of bits returned to earth by all other NASA spacecraft. The Outlook for Space themes imply a similar future increase over the Landsat capability. Simply pushing up the communication bit rate is a simplistic, expensive solution. A more cost effective approach is possible. The technology requirements that follow recognize that improvements throughout the information handling system are needed to keep up with the expected information flow from space. These improvements will result in lower information costs.

Software is recognized as a most fertile area of work. Since nearly all systems today, both flight and ground, require a large amount of software, even modest advances in software cost effectiveness would be welcome. A breakthrough would revolutionize data management.

Modular data processing architectures that build on standard functions will allow cost effective trade off between hardware and software and between central and distributed hardware approaches.

Improvements in high data rate processing will be required. These, if performed onboard, will convert "data" bits into fewer "information" bits. Often what is information and what is garbage cannot be determined until after an experimental phase is complete and an operational system is in place. However, with the possibility of a manned-interactive flight instrument, the information content may perhaps be deduced in real time, eliminating the need to transmit garbage.

Communication and wideband information transfer will exploit improvements in these technologies. It is recognized that information processing and software innovations are not likely to hold the bit rate down to today's levels. Cost effective systems will require considerably higher bit rates.

Improved data storage, both for the ground and especially for the spacecraft, is an essential ingredient of successfully meeting our cost and capability goals. Data storage system size, weight, power and cost are always high. In spacecraft it is usally higher than the rest of the data system combined. Processors have shrunk in size and cost due to LSI. Software could be cheaper if large, cheap memories were available; even communication links would be easier to build, since more processing could be done on the spacecraft. For instance, the Landsat spacecraft has a 15 megabit communications link. If a good 10^6 bit flight buffer memory had been available, this could have been reduced to about 6 megabits per second without disturbing the usable data in any way.

The Technology Requirements are individually quite narrow, but the improvements each holds out is needed in order to make cost effective information systems.

B. REQUIREMENT LISTINGS

Table IV-1 lists the detailed technology requirements developed by the Data Processing and Transfer Group. The listing is ordered by application to the major program thrusts identified in the preceding section, so that some technology requirements are repeated due to multiple applications. Each requirement is also identified by a code letter M or O designating it as "Mission Driven" or "Opportunity Driven". For this purpose, the following definitions were adopted by the Group.

> Mission Driven--Technologies required by missions described in the NASA 1973 Mission Model or by Outlook for Space/User inputs which are clearly within NASA's charter as the principal user.

> Opportunity Driven--Technologies which are required by Outlook for Space/User inputs outside of NASA's charter or which could provide the capability to perform functions not now proposed as future missions.

Tables IV-2 and IV-3 provide reference matrices which relate the technology requirements listed in Table IV-1 to the User Community and Outlook for Space inputs discussed in Section II, and to the major program thrusts of Section III. A detailed description of each technology requirement follows the tables in the order listed in Table IV-1.

DATA PROCESSING & TRANSFER
TECHNOLOGY REQUIREMENTS

(MAJOR THRUST #1 - 1000:1 INCREASE IN END-TO-END INFORMATION HANDLING)

ITEM #	DESCRIPTION	MISSION DRIVEN(M) OPPORTUNITY(O)
1A	<u>HIGH DATA RATE PROCESSING</u>	
1A1	RECOGNITION PROCESSING OF IMAGE TYPE DATA ON-BOARD SPACECRAFT	M
1A2	ON-BOARD PROCESSING OF MULTISPECTRAL SCANNER DATA	M
1A3	MODULAR PARALLEL PIPE-LINE PROCESSOR (MPPP)	M
1B	<u>INFORMATION EXTRACTION & DATA COMPRESSION</u>	
1B1	INFORMATION EXTRACTION & DATA COMPRESSION	M
1C	<u>WIDEBAND INFORMATION TRANSFER</u>	
1C1	LASER DATA TRANSFER	M
1C2	MILLIMETER WAVES FOR SPACECRAFT/SPACECRAFT DATA TRANSFER	M
1C3	HIGH CAPACITY KU-BAND COMMUNICATION TERMINAL	M
1C4	LOW COST RELIABLE MODULAR MICROWAVE COMMUNICATIONS ACTIVE ANTENNA	M
1C5	LIGHT WEIGHT TRANSPONDER	M
1D	<u>HIGH DENSITY, LOW COST STORAGE</u>	
1D1	ON-BOARD SOLID STATE DATA STORAGE SYSTEMS	M
1D2	LOW COST RANDOM ACCESS MEMORY	M
1D3	BULK DATA STORAGE FOR SPACECRAFT (10^{12} AND LARGER)	M
1D4	MASS MEMORY FOR PROCESSING ACQUIRED DATA	M
1E	<u>MODULAR ARCHITECTURE</u>	
1E1	MODULAR ARCHITECTURE FOR DATA PROCESSING & TRANSFER SYSTEMS	M
1F	<u>MANNED INTERACTION</u>	
1F1	VISION ENHANCEMENT & ASSISTANCE FOR TELEOPERATOR CONTROL SYSTEMS	O
1G	<u>COMMUNICATIONS</u>	
1G1	DIRECT BROADCAST/NARROWCAST SYSTEMS	O
1G2	SATELLITE DATA COLLECTION	O
1G3	TRUNKING & TELEPHONY SYSTEMS	O
1G4	SPECTRUM MONITORING TECHNOLOGY (RFI)	M

TABLE IV-1A

DATA PROCESSING & TRANSFER
TECHNOLOGY REQUIREMENTS

(MAJOR THRUST #2 - 10:1 LIFE CYCLE COST REDUCTION)

ITEM #	DESCRIPTION	MISSION DRIVEN (M) OPPORTUNITY (O)
2A	SOFTWARE	
2A1	COORDINATION OF NASA R & D IN COMPUTER & INFORMATION SCIENCE	M
2A2	SOFTWARE GENERATION & HUMAN-MACHINE INTERACTION	M
2A3	SOFTWARE MANAGEMENT	M
2A4	AUTOMATION OF GROUND SUPPORT FUNCTIONS	M
2A5	NETWORKING FOR NASA COMPUTER FACILITY & SOFTWARE SHARING	M
2A7	(1B1) INFORMATION EXTRACTION & DATA COMPRESSION	M
2A8	(1A1) RECOGNITION PROCESSING OF IMAGE TYPE DATA ON-BOARD SPACECRAFT	M
2A9	(1A2) ON-BOARD PREPROCESSING OF MULTISPECTRAL SCANNER DATA	M
2A10	(1A3) MODULAR PARALLEL PIPELINE PROCESSOR (MPPP)	M
2A11	(1C5) LIGHT WEIGHT TRANSPONDERS	M
2A12	(1D1) ON-BOARD SOLID STATE DATA STORAGE SYSTEMS	M
2A13	(1D2) LOW COST RANDOM ACCESS MEMORY	M
2A14	(1D3) BULK DATA STORAGE FOR SPACECRAFT (10^{12} AND LARGER)	M
2A15	(1D4) MASS MEMORY FOR PROCESSING ACQUIRED DATA	M
2B	ELECTRONICS & MODULAR ARCHITECTURE	
2B1	(1E1) MODULAR ARCHITECTURE FOR DATA PROCESSING & TRANSFER SYSTEMS	M
2B2	STANDARD ELECTRONIC MODULES FOR SPACE PAYLOADS & GROUND SUPPORT	M
2B3	FAULT TOLERANT ELECTRONIC SYSTEMS	M
2C	END-TO-END	
2C1	SYSTEM ENGINEERING TECHNIQUES USING MODELING & SIMULATION	M

TABLE IV-1B

DATA & PROCESSING & TRANSFER
TECHNOLOGY REQUIREMENTS

(GENERAL SUPPORTING TECHNOLOGY)

ITEM #	DESCRIPTION	MISSION DRIVEN(M)
GST-1	TRANSFER OF SPACE POWER BY MICROWAVES	M
GST-2	RADIATION TOLERANT ELECTRONIC COMPONENTS & SUBSYSTEMS	M

TABLE IV-1C

RELATIONSHIP OF USER REQ'S/TECHNOLOGY NEEDS/MAJOR THRUSTS

User Requirements		Major Thrusts	
User Office	Technology Needs	1	2
OA	Telephony, Trunking, Broadcasting	1B,1C,1G	2A11
	Earth & Ocean Physics		
	.Onboard Processing for 50-100 MBPS Imagery	1A,1B,1D1	2C1
	.Small Size, Large Capacity Ground Storage Systems (For Imagery)	1D	2A13,14,15
	.Improved Microwave Measurement Techniques	1A2	2A9
	Earth Observations		
	.1GBPS Data System With Onboard Processing	1C1	
	.Improved Cal Techniques fo High Rate Sensors	1A2	2A9
	.Filters With CCD'S for Onboard Synthetic Aperture Radar	1A2	2A9

Table IV-2a

Continued---RELATIONSHIP OF USER REQ'S/TECHNOLOGY NEEDS/MAJOR THRUSTS

User Requirements		Major Thrusts	
User Office	Technology Needs	1	2
OMSF	Improved Real-Time Image Enhancement	1F1	
	TV Over Standard Narrow Bank Links	1G4	
	Bandwidth Compression for Real-Time TV	1F1,1B1 1G1	2A7
OSS	Physics & Astronomy .High Density, Low Power Data Processing & Storage Systems	1A,1B	2A7,8,9,10
	.Long Life, Self-Repairing Spacecraft Systems	1E1	2B3
	.Improved Data Transmission & Data Handling Techniques	1A,1B,1C	2A7,8,9,10
OTDA	Higher Gain Steerable Spacecraft Antenna Systems for Deep Space	1C	
	X-Band Transponder for Deep Space Applications	1C5	
	K-Band Downlink for Deep Space Applications	1C3,1C4	
	10^{15} Mass Memory Storage with Fast Access, Small Volume, & Low Power Consumption	1D	2A12,13,14,15

Table IV-2b

OUTLOOK FOR SPACE TECHNOLOGY THRUSTS
AND
RELATED DATA PROCESSING & TRANSFER TECHNOLOGY REQ'S

TECHNOLOGY THRUSTS -- OUTLOOK FOR SPACE	WORKSHOP DATA PROCESSING & TRANSFER TECHNOLOGY REQUIREMENTS	
	Major Thrust-1	Major Thrust-2
*End-To-End Info. Management		2c
*Distributed Processing	1A1,1A2,1B1,1E1	2C1
*Mass Storage	1D	
*Software Production		2A,2B
*Info. Extraction & Representation	1A,1B	2C
*Large Antenna Aperture	1C4	
*Small Element Array	1C	
*LSI Microprocessors	1A	
*Semiconductor Mass Memory	1D	

Table IV-3

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1A1

1. TECHNOLOGY REQUIREMENT (TITLE): Recognition Processing Of Image Type Data On-Board Spacecraft PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: System

3. OBJECTIVE/ADVANCEMENT REQUIRED: To advance the technology of multispectral image data recognition processing to the point that such processing can be performed on-board spacecraft

4. CURRENT STATE OF ART: Recognition processors are currently being developed for use in ground processing of this type data at much lower data through-put rates HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

On-board recognition processing will require the development of
1) preprocessing systems to calibrate and format the data for recognition processing
2) high speed parallel processors to perform the recognition processing
3) high speed, high capacity random access digital storage devices
4) man interactive controls and displays necessary in the near term to assist and monitor the recognition process
5) digital computer controllers to control the flow of data through the recognition processor
6) scene analysis and location systems

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Earth resources type sensors (multispectral scanners, synthetic aperature radars, etc.) in the future will be capable of generating more data than the communication links can handle. One approach to reduction of the data transmission requirement is to perform the recognition processing on-board the spacecraft and transmit only the processed information to the ground station. This capability opens up a wide range of operating modes which range from data set selection to full scale recognition map making in space.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1A1

1. **TECHNOLOGY REQUIREMENT(TITLE):** Recognition Processing Of Image Type Data On-Board Spacecraft PAGE 2 OF 3

7. **TECHNOLOGY OPTIONS:**

1) Development of parallel processing systems capable of processing image data at least at the pixel data rate of the sensor preferably at faster than real time data rates to allow for training algorithm up dates during the processing.
2) Data storage technology must be advanced on a broad front. (i.e., high speed scratch pad memories, high speed disc like systems, and bulk storage systems)
3) Development of efficient man machine interfaces suitable for operations in a spacecraft environment.
4) Development of high speed general purpose, fault tolerant computer systems.
5) Development of on-board data aquisition systems designed to collect data from a wide variety of spacecraft sensors and present this data to the processing systems in a form that can be used to make decisions based on the inputs of multiple sensor systems.

8. **TECHNICAL PROBLEMS:**

1) Complex parallel processing at pixel rates up to 10^6 pixels per sec.
2) Real time training set selection.
3) Collection and up-link transmission of ground truth data.
4) Development of random access bulk storage systems with fast access times.
5) Determination of the pointing location of the spacecraft scanner relative to the location of ground truth in a real time environment.

9. **POTENTIAL ALTERNATIVES:**

Multi-gigabit data links

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

EXPECTED UNPERTURBED LEVEL ___

11. **RELATED TECHNOLOGY REQUIREMENTS:**

(see par. 7&8)

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1A1

1. TECHNOLOGY REQUIREMENT (TITLE): Recognition Processing Of Image Type Data On-Board Spacecraft PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Requirements Trade-Off Study		—	—																
2. Processor Design				—															
3. Fabrication					—														
4. Test						—													
5. Documentation						—													
APPLICATION																			
1. Design (Ph. C)						—													
2. Devl/Fab (Ph. D)							—	—											
3. Operations									—										
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					▽													
NUMBER OF LAUNCHES									3									3

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1A2

1. TECHNOLOGY REQUIREMENT (TITLE): On-Board Preprocessing Of Multispectral Scanner Data PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: System

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop the capability to perform multispectral scanner sensor calibration and data formating on-board the spacecraft.

4. CURRENT STATE OF ART: Preprocessing of this type is performed in ground processing facilities using conventional general purpose digital computers.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The processing necessary to meet this requirement involves interacting with the data stream from the sensor at real time data rates in the spacecraft environment. This interaction involves the following:

1) Calibration data stored in some spacecraft system prior to the mission
2) Dynamic calibration data produced by the sensor during the mission
3) Calibration data provided by other sensors and systems on-board the spacecraft
4) Calibration data transmitted to the spacecraft from the ground during the mission.

Preprocessing of this nature must be performed at high data rates and be adaptive in nature.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

One of the major data processing log jams in the present processing of earth resources type data is the necessity for calibration, correction and reformating of the data by ground processing facilities before it is available for recognition processing. Preprocessing the data on-board the spacecraft in real time would provide a significant reduction in the cost of processing earth resources type data as well as reducing the end to end processing time. In addition, this would reduce the requirements on the communications bandwidths also effecting a potential further cost saving. This type system is also a prerequisite for practical application of on-board recognition processing.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY RE . JIREMENT NO. 1A2

1. TECHNOLOGY REQUIREMENT (TITLE): On-Board Preprocessing Of Multispectral Scanner Data

7. TECHNOLOGY OPTIONS:

Several approaches to this task exist. One approach would be to incorporate the preprocessing as part of the sensor system. This approach may allow the calibration to be performed at the analog level there by reducing the high speed data requirements. It may also be possible to organize and sensor system such that reformating of the data is unnecessary. An all digital approach which need not be an intimate part of the sensor system could provide sufficient flexibility to operate with a variety of sensors without a separate system development for each sensor. An all digital approach however would likely encounter more difficulty with the high data rates involved.

8. TECHNICAL PROBLEMS:

1) Calibration algorithm determination
2) Collection of calibration data in real time
3) High data rate parallel processing
4) Resolution and accuracy
5) Calibration confidence verification
6) Lack of agreement on optimum formats for processing scanner data.

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

See 7&8

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 1A2

1. TECHNOLOGY REQUIREMENT (TITLE): On-Board Preprocessing Of Multispectral Scanner Data — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Requirements Study		—																	
2. System Design		—																	
3. Fabrication of Prototype			—	—															
4. Test				—															
5.																			
APPLICATION																			
1. Design (Ph. C)					—														
2. Devl/Fab (Ph. D)						—	—	—	—										
3. Operations							—	—	—	—	—								
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				∇														
NUMBER OF LAUNCHES							1	1	1	1	1							5

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1A3

1. TECHNOLOGY REQUIREMENT (TITLE): Modular Parallel Pipe-Line Processor (MPPP) PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: System

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of a modular high speed parallel pipe-line processor capable of supporting the requirement for on-board multispectral processing

4. CURRENT STATE OF ART: Parallel pipe-line processors are being used for data processing of multispectral data in ground data processing facilities at much lower data rates than required. HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The Modular parallel pipe-line processor will be composed of a variety of computation modules each of which will be capable of performing a specific task (i.e. addition of vectors, multiplication of vectors, calculation of determinants, etc.). Each module connects with a segmented buss structure such that the order and combination of the modules connected to the buss determines the basic algorithm to be processed. Additional control of the algorithm and data flow is determined by the constants and control vectors entered at critical points in the algorithm flow by the control computer.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Both the preprocessing and recognition processing of high data rate earth resources image data will require a high speed parallel processor. A modular structure as described above will allow sufficient flexibility to use the MPPP with a variety of sensor and processor requirements without requiring a separate hardware development for each application, thus enabling a cost effective approach to on-board parallel processing.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1A3

1. TECHNOLOGY REQUIREMENT(TITLE): Modular Parallel Pipe-Line Processor (MPPP) PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Although the required module functions can be fabricated using standard off the shelf digital logic, neither the form factors (size, weight, etc.) nor the resulting power consumption would be suitable for spacecraft use. A new device technology or significant advancements in current technologies must be achieved before the maximum advantage of a system like this could be realized. Near term objectives should however begin concentrating on developing prototype systems to verify the concept and encourage the development of technology necessary for the spacecraft implementation. Non-flight qualified versions of the concept could be put to use processing earth resources data on the ground.

8. TECHNICAL PROBLEMS:

1) High speed, low power complex digital integrated circuits are required which are not currently available.
2) Size, weight, and power requirements without integrated circuit technology advancements.

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Integrated circuit development in the area of high speed, low power devices for complex arithmetic and logical functions.

High speed semiconductor random access memory technology.

High speed fault tolerant computers for aerospace applications.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1A3

1. TECHNOLOGY REQUIREMENT (TITLE): Modular Parallel Pipe-Line Processor (MPPP) PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis/Design	—	—																	
2. Fabrication		—	—																
3. Test				—															
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE			▽														
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1B1

1. TECHNOLOGY REQUIREMENT (TITLE): Information Extraction And Data Compression--Both Earth-Orbital And Planetary Flight PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Data Processing and Transfer

3. OBJECTIVE/ADVANCEMENT REQUIRED: Pre-process and process on-board sensor data in a distributed flight data system which then compresses data centrally for transmission to ground.

4. CURRENT STATE OF ART: Raw and monor preprocessed data is interleaved/multiplexed for transmission to the ground with some moderate compression. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

Incorporate in sensor output(s) the necessary sensor calibration and conversion algorithms to more nearly select or discriminate the desired intelligence in meaningful units such that only the useful data are taken. Next, provide distributed microprocessors and tailored software associated with each stand alone sensor or group of related sensors (experiment) to discard irrelevant and repetitive information. Only initial state and subsequent change data should be provided to the vehicle central processor for transmission to the ground for image data which a user insists be transmitted to the ground, only those frames which exhibit predetermined change characteristics should be provided or only the affected portions of those frames. The vehicle central processor should provide the vehicle time base and should perform data interleaving and data compression (up to 1000:1). The system (Continued on page 4)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The magnitude of data to be processed will be staggering based on plans for future earth-orbital and planetary missions involving continuous or near-continuous measurements from complex sensors. If on-board pre-processing and processing are not significantly increased to transmit only what is relevant to the problem at hand, the impact on down link communications will be to exceed its capability. Furthermore, the major volume of data generated will have to be stored/processed in ground-based facilities with longer loop time for experiment analysis and modification.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1B1

1. TECHNOLOGY REQUIREMENT(TITLE): Information Extraction And Data Compression PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

Location of on-board processing (central vs. distributed) and the extent of man interaction for manned vehicles provides options within the basic technology area.

8. TECHNICAL PROBLEMS:

To discriminate the desired/significant intelligence from sensor outputs, particularly when many items can be determined from complex sensors, and to represent the relevant results in efficient terms poses a major problem in information science. Also, data compression of the desired magnitude without increasing error rates poses a problem of low-noise time-stable circuitry.

9. POTENTIAL ALTERNATIVES:

Increase communication link data transfer capacity and enlarge ground-based data processing/storage facilities.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Sensor technology advancement.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1B1

1. TECHNOLOGY REQUIREMENT (TITLE): Information Extraction And Data Compression

PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. System Concept																			
2. System Design																			
3. Fabrication																			
4. Test & Demo																			
5. Documentation																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations											Δ								
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE								Δ										
NUMBER OF LAUNCHES																		

14. REFERENCES:

Outlook For Space

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1B1

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE OF 4

Information Extraction And Data Compression

should be adaptive to the extent that the system gains/sensitivities, sensor fields of view, conversion factors, compression ratios, etc. can be modified either by man, ground processor, or vehicle processor based on P.I. decisions, predetermined conditions, etc. (dependent on permissible loop time).

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1C1

1. TECHNOLOGY REQUIREMENT (TITLE): Laser Data Transfer PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: System

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide wideband (up to one gigabit) data transfer capability for space-to-space data links

4. CURRENT STATE OF ART: Engineering model systems have been demonstrated in laboratory operations.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Laser heterodyne systems operating at 10.6 microns with 25 centimeter telescopes as antennas at both the receiving and transmitting stations can provide data rates up to 500 megabits per second with currently available technology. Nd: YAG systems operating at 1.06 microns in a direct receive mode with 40 cm. telescopes at the transmitter and 60 cm. telescopes at the receiver have been operated at rates up to one gigabit in the laboratory. Both systems have potential to meet the stated requirements. Space testing is necessary to verify laboratory performance, identify operational limitations, and qualify laser systems for space applications.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☒ C/D

6. RATIONALE AND ANALYSIS:

a) Laser systems offer the most effective and economical approaches to achieving data transfer rates in the gigabit per second range.
b) All earth observation satellites plus planetary spacecraft operating with imaging systems or other types of high data rate sensors would benefit from this technology.
c) Wideband data transfer would permit operation of sensors at maximum resolution and sensitivity limits and lessen the requirement for on-board storage or processing of data.
d) Space testing is needed to eliminate unknowns and minimize risk in operational applications. The system should be operated in a typical data link over an extended period of time to assess operating margins, tracking and acquisition capabilities, and laser operating life in a space environment.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1C1

1. TECHNOLOGY REQUIREMENT(TITLE): Laser Data Transfer PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Primary option is to trade off between coherent and noncoherent approaches. Coherent system is limited by available modulation techniques to about 500 megabits per second. Research on improved modulator/demodulator technologies is being conducted under current R & D programs.

Noncoherent approach requires larger antennas (telescopes) to provide needed link margins due to limited power and efficiency of lasers. Efforts to improve laser efficiency are underway also.

8. TECHNICAL PROBLEMS:

Problem areas include laser lifetime, laser pumping techniques, modulator techniques and detector response time.

9. POTENTIAL ALTERNATIVES:

Alternative approaches include extension of current microwave systems technology to higher frequencies and the development of millimeter wave systems to improve the data relay link capability. On-board data handling and processing technology provides an additional alternative where total data return is not required.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Continuing laboratory R & D activities can provide more efficient lasers, modulators and detectors (RTOP 506-20-23), but will not provide needed space tests. Planned AF experiment will demonstrate Nd:YAG system in space-to-ground mode in 1980, but cannot answer questions on space-to-space system operation.

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Advanced data storage and processing techniques in ground based systems will be required to handle the increased data flow resulting from this technology.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. 1C1

1. TECHNOLOGY REQUIREMENT (TITLE): Laser Data Transfer

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Prototype Design & Test																			
2. Flight Model Fabrication																			
3. Spacecraft Integration																			
4. Flight Test																			
5. Operational System Specification																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE							∇	(2nd Generation TDRSS)									
NUMBER OF LAUNCHES	To be determined by approved mission model																

14. REFERENCES:

1. NASA Laser Data Relay Link Experiment for the DOD/NASA Cooperative Space Laser Communications Flight Test, Volumes I and II, GSFC, May 1974.

15. **LEVEL OF STATE OF ART**

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1C2

1. TECHNOLOGY REQUIREMENT (TITLE): Millimeter Waves For Spacecraft/Spacecraft Data Transfer

PAGE 1 OF 2

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of space data transfer terminals operating in millimeter-wave bands.

4. CURRENT STATE OF ART: Millimeter-wave communications have allegedly been developed for space use by the Department of Defense. However, that work is so highly classified that information is not readily available and the technology is not accessible.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The whole range of data transfer terminal components and techniques must be developed. This includes antennas, receivers, transmitters, and modulation. The requirement which exists is for a system that provides gigabit data transfer in point-to-point space communications. Specific tradeoffs such as antenna size vs. transmit power must await detailed data.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Data transfer at the customary frequencies (S and Ku-Bands) involves sizable antennas. More importantly, space-to-space links are subject to CCIR guidelines restricting power density impingement on the earth. This causes the requirement of spreading the transmitted spectrum and complicates system operation. Millimeter waves are absorbed by the atmosphere and are not subject to spreading requirements. Antennas at millimeter wavelengths are miniscule and allowable data rates are extremely large, with gigabit channels feasible. Development of such channels would provide a viable candidate for future space-space data transfer links.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1C2

1. **TECHNOLOGY REQUIREMENT(TITLE):** Millimeter Waves For Spacecraft/Spacecraft Data Transfer **PAGE 2 OF 2**

7. **TECHNOLOGY OPTIONS:**

Data limited

8. **TECHNICAL PROBLEMS:**

Data limited

9. **POTENTIAL ALTERNATIVES:**

Laser Data Transfer

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

Embryonic technology. Progression unpredictable. Technology data is classified.

EXPECTED UNPERTURBED LEVEL __

11. **RELATED TECHNOLOGY REQUIREMENTS:**

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1C3

1. TECHNOLOGY REQUIREMENT (TITLE): High Capacity Ku-Band Communication Terminal PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development/Demonstration of a spacecraft Ku-Band Communication terminal compatible with TDRSS operation, with color TV capability on the forward link and 200 MBPS capability on the return link.

4. CURRENT STATE OF ART: Shuttle Orbiter is developing a terminal that is marginal at 1 MBPS on the forward and 50 MBPS on the return link.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Required components are a Ku-Band 5 foot-equivalent unfurlable antenna, integrated with a 25 watt solid state up-converter/power amplifier and a parametric amplifier/image-enhanced down-converter. This package must fit in the space allocated to the Orbiter 20 inch dish. It is likely that a flexible heat pipe will be required to provide some temperature stabilization.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☒ C/D

6. RATIONALE AND ANALYSIS:

The Shuttle Orbiter has been designed to carry a 20 inch dish to allow payload access to wideband data transfer through TDRSS on Ku-Band. A larger rigid dish is not feasible, and the power budget with this dish is very restrictive. While the margins are still in a state of uncertainty, it is problematical whether a one megabit forward link and a 50 megabit return link can be maintained. These data rates by no means saturate TDRSS capability or satisfy all projected user requirements. A five foot-equivalent unfurlable dish would give an order of magnitude improvement in capability. To gain further improvements, the Ku-Band electronics should be integrated with the antenna, allowing low-loss spacecraft interfaces without use of pressurized wave guides with rotating joints. This would require development of a solid state power amplifier (25 watts should be readily achievable with FAAs technology) with integral up-converter and a parametric preamplifier with integral image-enhanced down-converter. These components (antenna, preamp and poweramp) should all be developed with the goal of integration so that antenna structures may serve as part of the electric housing, thereby minimizing gimbaled mass. It is probable that a flexible heat pipe will be required to stabilize temperatures on the antenna. Such a system would allow higher performance while using flexible media such as coaxial cable.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1C3

1. TECHNOLOGY REQUIREMENT (TITLE): High Capacity Ku-Band Communication Terminal

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Component Development	—	—	—	—	—														
2. Terminal Design					—	—	—												
3. Demonstration System Flight								*											
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)						—	—												
2. Devl/Fab (Ph. D)							—	—											
3. Operations								*											
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE						X											
NUMBER OF LAUNCHES									25	25	25	25	25				

14. REFERENCES:

Outlook for Space, Workshop Users Guide, Shuttle Systems Description

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 103

1. TECHNOLOGY REQUIREMENT(TITLE): High Capacity Ku-Band Communication Terminal

7. TECHNOLOGY OPTIONS:

Power level and antenna size may be traded on the return link. Very little can be accomplished on the forward link to reduce system noise temperature and increase data transfer without increased antenna size.

8. TECHNICAL PROBLEMS:

The components should not be exceptionally difficult to develop. However, integration into a functioning whole may prove more difficult. Thermal control, gimbaled mass minimization and size may prove to be problems.

9. POTENTIAL ALTERNATIVES:

Little can be done with the present TDRSS implementation to improve performance without attacking antenna size and losses. In the long term, lasers or millimeter waves may replace the Ku-Band space to space links.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

A JSC RTOP (909-44-07) is addressing the antenna/electronics integration at a low level using existing components. A requested GSFC RTOP would initiate Ku-Band solid state power amplifier work. The USAF Avionics Laboratory is developing X-band GaAs power amplifiers. The required terminal is not likely to be available by 1985 at present levels of activity.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Flexible heat pipes.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 104

1. TECHNOLOGY REQUIREMENT (TITLE): Low Cost Reliable, Modular, Microwave Communications Active Antenna PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Made a radical improvement in the reliability of communication links through the development of solid state, transmit-receive, phased arrays.

4. CURRENT STATE OF ART: Power generation is by single tubes, or solid state devices, and therefore subject to catastrophic failure. Phased arrays have been too expensive and complicated. HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The recent demonstrations of Gallium Arsinide field effect devices as power generators and detectors at microwave frequencies protends the development of a family of apertures, producible at a reasonable price ($100.00 per module) and assemblable into highly reliable, gracefully degrading arrays for communications or radar systems. The following steps are required--

(1) Study and design a set of link requirements (Power, Gain, Bandwidth, Noise Figure etc.).
(2) Interprete requirements into device and module specifications.
(3) Develop modules and assemble into arrays.
(4) Test arrays for BW, Power etc.
(5) Demonstrate arrays in shuttle orbitor.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a.) This technology affects every payload and vehicle that has a communications function. A typical application would be the shuttle orbitor which has a requirement for a 25 watt, 50 megahertz, Ku-band link. This appears to be well within the technology potential.
b.) Links should be designed for Satellite to Satellite, Satellite to ground, vehicle to Satellite, vehicle to vehicle range of applications.
c.) Reliability of communications and therefore mission performance and length of life should be improved by 10:1.
d.) The theory and devices are at level 4 and now levels 5, 6, 7, 8 should be accomplished.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 104

1. TECHNOLOGY REQUIREMENT(TITLE): Low Cost Reliable Modular Microwave Communications Active Antennas PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

1) Microwave tubes (remote) and steerable dishes.
2) Solid state devices (local) and steerable dishes.
3) 1 or 2 and phased array.
4) Distributed solid state transmitter-receivers and phased arrays. This allows electronic scanning of beams and the elimination of motors, gears, cams, Rotary joints and other items of potential failure.

8. TECHNICAL PROBLEMS:

This innovative technology appears to have no foreseeable problems other than funding and accomplishment.

9. POTENTIAL ALTERNATIVES:

(1) Use silicon and varactor multipliers to make the solid state transmitters and receivers (more expensive and lower reliability).
(2) Stay with present technology and suffer cost, performance, and reliability loss.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

(1) The US Air Force is actively programming for GaAs devices and an A-A/A-G Radar using this technology ($1.0M/year)

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

High Bandwidth modulators and signal processing must be combined with these apertures to make a communications system. Also heat pipes.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 104

1. TECHNOLOGY REQUIREMENT (TITLE): Low Cost Reliable Modular Microwave Communications Active Antennas

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Define & Design	—	—																	
2. Develop +		—	—																
3. Test				—															
4. Space Demonstrations (Shuttle orbitors)				—	—	—													
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations						X													
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE						X											
NUMBER OF LAUNCHES																	all

14. REFERENCES:

Air Force Avionics Laboratory TOP-T1

Mr. W. J. Edwards 513-225-2911

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1C5

1. TECHNOLOGY REQUIREMENT (TITLE): Light Weight Transponder PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: System

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide high efficiency, lightweight transponders for space communication systems operating in the 7.5-35 gigacycle band.

4. CURRENT STATE OF ART: Supporting technologies are being developed and demonstrated in laboratory R & D efforts.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Spaceborne transponders using solid state technologies to achieve signal detection, processing and transmission at the upper limits of the microwave spectrum including:

- Surface acoustic wave filters and oscillators.
- Solid state transistor power amplifiers capable of 2-5 watts output at 7.5 and 15 gigacycles per second.
- Paramp receivers operating at 15 to 35 gigacycles with insertion losses less than 2 dbw.
- Signal conditioning and processing techniques which can compress band width requirements at least one order of magnitude.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) Future missions will operate at the upper limits of the microwave spectrum to achieve maximum band width with minimum cost in terms of antenna size, system weight and power. Data relay systems will require maximum use of solid state technology to minimize maintenance and replacement costs.

b) All spacecraft using transponder technique to maintain communication with earth stations or other spacecraft.

c) Solid state technology offers lifetime in the 5-10 year range compatible with deep space missions, X, Ku and Kx band components offer data rates to 250 gigabits per second. 10:1 reductions in power consumption and weight are feasible using advanced technologies.

d) Extensive R & D is needed to develop solid state power amplifier and demonstration system operation in the laboratory under typical space environmental conditions.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 1C5

1. TECHNOLOGY REQUIREMENT(TITLE): Light Weight Transponder — PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Continued operations with current technology severely constrains data transfer rates and efficiency of space operations.

Switch to Ku band with TDRSS will increase data rate capabilities, but currently requires large antennas and TWT systems on user spacecraft due to limited availability of solid state components.

Development and demonstration of solid state technologies at the upper limits of the microwave spectrum can provide more efficient, lightweight transponder capability without major increase in system implementation and operation costs.

8. TECHNICAL PROBLEMS:

Break-through type of advancements in solid state RF transistors are needed to guarantee required performance.

9. POTENTIAL ALTERNATIVES:

Millimeter wave and optical communication systems offer similar performance capabilities. Trade-off studies indicate optical systems are less cost effective for missions where data rates are of the order of 200 megabits per second or less.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Current R & D programs are examining solid state RF power amplifier technologies for Ku band. Surface acoustic wave filters, oscillators and frequency synthesizers at S, X and Ku bands are being developed under several NASA and DOD sponsored programs. Extension to higher frequencies is urgently needed.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

Antenna pointing and control techniques compatible with the narrow beam widths of higher frequency systems will have to be demonstrated.
New antenna structures and feed systems may be needed to provide efficient transmission and reception capability.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1C5

1. TECHNOLOGY REQUIREMENT (TITLE): Light Weight Transponder — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Component Development	—	—	—	—															
2. System Design		—	—	—															
3. System Fabrication & Test				—	—	—													
4. Laboratory Operation						—	—												
5. Documentation							—												
APPLICATION																			
1. Design (Ph. C)									—	—									
2. Devl/Fab (Ph. D)										—	—	—							
3. Operations												—	—	—	—	—	—		
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE								▽										
NUMBER OF LAUNCHES		To	be	determined														

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1D1

1. TECHNOLOGY REQUIREMENT (TITLE): On-Board Solid State Data Storage Systems PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: System

3. OBJECTIVE/ADVANCEMENT REQUIRED: Development of low cost, low power, high density data storage memory technologies, and data storage systems using these technologies

4. CURRENT STATE OF ART: Magnetic tape recorders are the only currently available system

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

The following requirements have been identified:

1. High Reliability--MTBF=10,000 hours plus graceful degradation
2. Rapid Random Access at least to the block level
3. Large Capacity-=10^9 Bits
4. High Data Transfer Rates--up to 25 MHZ
5. Low Power--Very Low Power for stand by and low data rates=50 watt peak power at maximum data rate
6. Low Cost
7. Low Volume and Weight

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Almost all data collection and information systems aboard spacecraft will require some form of data storage. The present requirement driver is the need to store spacecraft data until down link opportunities are available. Future use of on-board data processing may require additional on-board storage necessary to buffer sensor data prior to processing, to store intermediate and final processed information, and to store processing and analysis software programs.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1D1

1. TECHNOLOGY REQUIREMENT(TITLE): On-Board Solid State Data Storage System PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

At least two data storage technologies currently being investigated offer promise for fulfilling these requirements. They are the magnetic domain wall motion devices like bubbles, cross-tie memories, etc. and semiconductor charge storage devices like Difmos Devices and CCD's. Research and development in these or other areas of Data Storage Technology will be required to meet future objectives. Bubble Domain Devices have been developed which contain 10^5 bits per chip and data storage systems are currently being developed having capacities up to 10^8 bits. Even though these developments look very promising, higher density chips, higher on chip data rates, and simplified magnetic interfaces will have to be developed before requirements projected for the late 1980's and beyond can be met.

8. TECHNICAL PROBLEMS:

Bit Storage Density
Data Rates and Access Times
Implemention Form Factor (size, weight, power, etc.)

9. POTENTIAL ALTERNATIVES:

Magnetic tape or rotating devices like disc or drum memories.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

NASA is currently developing a 10^8 bit Bubble Data Recorder under RTOP 520-71-01.

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Basic research in memory storage device technology.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1D1

1. TECHNOLOGY REQUIREMENT (TITLE): On-Board Solid State Data Storage Systems — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Material & Process Research																			
2. Device Design & Development																			
3 System Design																			
4. System Fab.																			
5. Test																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1D2

1. TECHNOLOGY REQUIREMENT (TITLE): Random Access Memories For Low Cost Computer Systems PAGE 1 OF 2

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Obtain random access memories for flight costing less than 1 cent per bit.

4. CURRENT STATE OF ART: About 20 cents per bit in cores and about 50 cents per bit in plated wire.

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Various integrated circuit technologies hold the promise of lowest RA memories. A combination of these technologies with electron beam storage is also possible.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The major (60% to 80%) hardware cost in flight computer systems is the RA memory. This memory stores the program and the data that is being worked on by the computer. Because of this expense, software cost is considerably higher than it would be if RA memory was plentiful and inexpensive. Technology improvements aimed at lower cost RA memories will directly result in lower cost data processing systems.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1D2

1. TECHNOLOGY REQUIREMENT(TITLE): Random Access Memories For Low Cost Computer Systems

PAGE 2 OF 2

7. TECHNOLOGY OPTIONS:

Traditional approaches to RA memory are slowly decreasing in cost. Cores and plated wire are used in most of today's systems. New approaches such as integrated circuits and perhaps electron beam devices hold promise for lower cost systems. The wavelength allows a very compact device. Holographic systems may also be applicable.

8. TECHNICAL PROBLEMS:

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Advances are small, incremental. Ground RA costs are slowly coming down. Flight requirements are somewhat unique to NASA's requirements and are not being directly addressed in other programs.

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 1D3

1. TECHNOLOGY REQUIREMENT (TITLE): Bulk Data Storage For Spacecraft (10^{12} And Larger) — PAGE 1 OF 2

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED:

4. CURRENT STATE OF ART: Low cost wide band type recorder has a capacity of 3×10^{11} is in early stages of development

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

The only current technology that can be expected to handle the capacity and be reasonable in terms of size, weight, power, and cost is magnetic tape. The original Landsat Wide Band Video Tape recorder extended the lifetime capability over conventional ground based Video tape recorders by a factor of four. Its performance in orbit of 1000 hours of operation before the tape wore out allowed it to playback to the ground more than 20 times the data played back from all other NASA recorders. A program to extend the life of Landsat C is underway and those improvements will extend its life at least a factor of 10.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Landsat VTR packed almost 10^6 bits on each square inch of tape surface. Packing densities of 5×10^6 bits per square inch have been demonstrated. Higher densities are limited by the thickness of the magnetic coating. Long wearing high remnance coatings less than 20 micro inches are needed. If 10 micro inches could be obtained a density over 10^8 per square inch might be achievable. Very large (10^{13}) storage systems are possible even with today's demonstrated packing densities, but the mechanics of moving 40,000 ft. of 4 inch wide tape are expensive. However, at 10^8 bits per square inch, only 6000 feet of 2" wide tape is needed.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1D3

1. TECHNOLOGY REQUIREMENT(TITLE): Bulk Data Storage For Spacecraft (10^{12} And Larger) PAGE 2 OF 2

7. TECHNOLOGY OPTIONS:

The rapid access of large holographic systems is not required. Continuous transmissions to the ground through TDRS is a possibility, but this assumes TDRS availability at all times. Also a reduced rate playback while the satellite is over uninteresting areas of the world (water) might be needed just to get the data to the TDRS.

8. TECHNICAL PROBLEMS:

The very short recorded wavelengths require that substantially thinner magnetic coatings be achieved. Present coatings are in excess of 100 microinches. This might be reduced by an order of magnitude. Solutions to the head-tape wear problem have been demonstrated in laboratory life tests. These solutions are being integrated into new recorders.

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

NASA's flight recorders have the most to gain by technology improvements. Most other uses are ground uses and rolls of magnetic tape are relatively cheap compared to the high density machines described above.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

General electronic reliability improvements are needed to really get these complex high capacity recorders to be truly reliable components.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1D4

1. TECHNOLOGY REQUIREMENT (TITLE): Mass Memory For Processing Acquired Data PAGE 1 OF 2

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Extend mass storage from presently planned 10^{12} bits to 10^{15} bits storage.

4. CURRENT STATE OF ART: TELOPS is planned at 10^{12} bits storage.

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Data collected by spacecraft must be processed prior to transmission to the ultimate user. Since this processing usually requires data from many sources, the data must be stored in a mass memory. The sources might be altitude, orbit, ground truth and data from other spacecraft. Also, our image producing spacecraft produce most of their data over land masses. The mass memory then provides a storage capability to smooth out data flow, allow optimum use of the processing machines and makes best use of the various communicative resources.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

It is clear that the cost per bit of this system will have to be very low. Even if the facility were to cost \$10 million, the cost per bit would have to be less than 10^{-6} cents. This is several orders of magnitude below today's mass memory bit costs and will require improvements in all mass storage technologies. Magnetic tape has the advantage of relatively cheap storage media, but the disadvantage of rather long access time (10's of seconds). This may be satisfactory if data is stored in very large blocks, say 10^{10} bits or more. The tape would also serve the off line storage functions without additional transcribing. It is estimated that 30 tape machines each holding a 10,000 ft. reel of 3" wide tape and using a packing density of 10^8 bits per square inch would do the job. This is only a one order of magnitude improvement in density over laboratory systems of today.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): Mass Memory Of Processing Acquired Data PAGE 2 OF 2

7. TECHNOLOGY OPTIONS:

Holographic systems are presently at capacities of 10^{12} bits or more. This is expected to rapidly improve as media improves and bit densities go up. Access time to any bit will be short--a few micro seconds or less. Electron beam recorders are also a possibility. Because the electron beam wavelength is so short compared to light waves, very high resolution at the storage medium is possible.

8. TECHNICAL PROBLEMS:

For tape systems, thin coating of media is required (10 to 20 microinch thickness). For Holographic systems, storage media improvements are required. For electron beam systems, target media that fully takes advantage of the resolution must be developed.

9. POTENTIAL ALTERNATIVES:

Bubbles and CCD's are potential alternatives. However, the per bit costs associated with these must drop drastically before a 10^{15} mass storage system can be built from these technologies.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Other government users have sponsored large data stores in the past. For instance, Ampex delivered a Tera bit (10^{12}) tape storage system in the early 1960's. NASA's need to handle large numbers of high resolution, multispectral pictures during the 1980's may require sponsorship of a 10^{15} bit system by NASA.

EXPECTED UNPERTURBED LEVEL

11. RELATED TECHNOLOGY REQUIREMENTS:

Very high communication channel capacities. For instance, if the 10^{15} bit store was to be filled in one day, the average bit rate into the device would have to be 12 gigabits/sec. (12,000 megabits/sec).

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1F1

1. TECHNOLOGY REQUIREMENT (TITLE): Vision Enhancement And Assistance For Teleoperator Control Systems PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Improve and supplement displays of images transmitted from remote teleoperator television cameras to give the operator better knowledge of the task environment and of effector actions.

4. CURRENT STATE OF ART: Most current teleoperator vision systems do not provide adequate knowledge of the remote sites for efficient and comfortable operator control. HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Many tasks conducted in space require the manipulation of objects or the motion of vehicles in complex and possibly hazardous environments whose features cannot be predicted or controlled. Examples of such tasks are shuttle payload deployment, servicing of payloads by free-flying teleoperators, and lunar roving vehicle operations. When these tasks cannot be done by placing a human worker at the site, they must be conducted by remote control. A teleoperator system is one that enables an operator (on Earth or in the Shuttle for example) to operate remote effectors while observing the task environment on displays of television images transmitted from the site. The technology covered in this requirement concerns the type and quality of the information made available to the operator. Specifically, three types of information processing are addressed: 1) Enhancement of TV images to emphasize features needed for operator decisions; 2) Use of bandwidth compression techniques to improve the amount of useful information that can be transmitted in real time over a bandwidth limited channel; 3) Generation of displays based on (Continued on 1a)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

1) Enhancement. Operator viewing of teleoperator television cameras requires sharp imaging of the target. Image processing techniques are required will render the images presented to the operator more useful. Enhancement of target outlines is required. The operator should be able to select certain areas of an image and filter the TV data according to various criteria in real time. Processes now performed on TV images must be speeded up to permit a real-time interaction of the operator with the image information.

2) Compression. Real-time mono and stereo TV pictures are essential to teleoperator control. Bandwidth requirements for the transmission of such pictures, especially if they are in color, are excessive for many space applications. Improvement of scene analysis techniques is needed so that data of no use to the operator are not transmitted, while the information of most use to him (object relationships to one another, outlines, distances, heights, etc.) is extracted interactively, transmitted, and displayed for use in real-time.

3) Generation. An operator controlling a remote effector over a communication link, using only the information provided him by a television camera, does not have the same view of the task environment that he would acquire if he (Continued on Page 1a) TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1F1

1. TECHNOLOGY REQUIREMENT (TITLE): Vision Enhancement And Assistance For Teleoperator Control Systems PAGE 1a OF 4

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED:

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY (Continued from page 1)

non-visual information, such as the positions of manipulator joints or wheel positions and orientations, that will supplement the visual information and give the operator a more complete overview of the work site. Such displays will be especially useful because it is found in practice that the operator cannot gain adequate knowledge of the effector configuration in relation to the workspace from TV images alone.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

were actually at the site. As a result, it is found that the time required to perform the task may go up by a factor of ten or more, and the operator finds the task demanding and tiring. Other types of information need to be extracted, telemetered, and combined to give the operator a more complete feeling of involvement. The feedback of force and tactile information has long been considered and is being pursued. Other useful data would be effector positions and highly filtered information (of the kind discussed in (2) concerning the characteristics of the environment. The focus in this portion of the requirement is on the development of displays that give the operator a bird's eye view of the entire work site - effector system plus environment. This display can be driven by the same information that drives the actual effector. For critical operations, planned actions can be tested in real time on the display before they are actually executed. The displays should be capable of being rotated while in motion so that they can present the remote scene from a variety of useful perspectives.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1F1

1. **TECHNOLOGY REQUIREMENT(TITLE):** Vision Enhancement And Assistance For Teleoperator Control Systems

7. TECHNOLOGY OPTIONS:

1) Enhancement
   - A) Develop highly parallel hardware systems for on-board image data preprocessing and feature extraction.
   - B) Develop fast on-board serial computers for image preprocessing and ground systems for real-time image environment. (This approach is, however, not compatible with (2).)

2) Compression
   - A) Develop scene analysis techniques and combine them with classical source encoding methods.
   - B) Close some effector control loops on-board and transmit only highly filtered data to the operator.

3) Generation
   - A) Transmit data sufficient to drive a simulation (display).
   - B) Use full-scale models for partial site recreation.

8. TECHNICAL PROBLEMS:

1) Enhancement - Hardware and algorithm development

2) Compression - Scene analysis

3) Generation - Developing a real-time simulator matched to user needs

9. POTENTIAL ALTERNATIVES:

a) Use an astronaut where feasible to perform the task (EVA)
b) Increase the communication bandwidth and transmit all data needed; perform all real-time data reduction and processing in large ground systems.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a) Shuttle payload manipulation
b) Free-flying teleoperators for payload servicing

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Reliable high-capacity on-board processors
Scene-analysis algorithms
Robotics

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1F1

1. TECHNOLOGY REQUIREMENT (TITLE): Vision Enhancement And Assistance For Teleoperator Control Systems — PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Develop source encoding & scene analysis methods																			
2. Design spaceborne imaging & preprocessing hardware																			
3. Design and code simulation system								∇											
4. Prototype																			
5. Flight test										∇									
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE											∇							
NUMBER OF LAUNCHES			All flights after acceptance															

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 1E1

1. TECHNOLOGY REQUIREMENT (TITLE): Modular Architecture For Data Processing And Transfer Systems — PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide a system consisting of modular components and functions to better meet the needs of advanced spacecraft and experiments through modular LSI technology.

4. CURRENT STATE OF ART: Presently the processor, memory, I/O, and related functions are collected centrally resulting in complex functions being performed by a large central system. HAS BEEN CARRIED TO LEVEL 1

5. DESCRIPTION OF TECHNOLOGY

A very modular, adaptable system is required where processing units are located at, and integrated with various functional spacecraft subsystems such as T, T, & C, Sensors, G&N, Power, and Propulsion. Functionally specific hardware and software would be a part of the particular subsystem. System elements would be functionally interchangeable and designed for fault tolerance and isolation. Commercially developed microprocessors and memories should be considered for use wherever possible.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

To date the approach to on-board data processing and transfer systems has been to centrally locate the processor memory, I/O, and software. As requirements have grown so has the complexity and size of the various system elements. The need for longer life systems has posed an additional problem since system elements are already so complex, fault tolerance and correction cannot easily be accommodated. Most current approaches to this problem result in multiply redundant system elements; elements already large and complex. As requirements on the data processing system have increased so has the software complexity. Since the software now resides in a single processor/memory this has given rise to problems in software interaction, and difficulty with additions and changes when they are required. Sophisticated operating systems and programming languages have become necessary to cope with this burgeoning problem.

With the advent of the microprocessor and other LSI devices the opportunity now arises to consider the possibility of distributing the functions of the data processing system among the user elements. For example, a processor unit could become a part of a sensor subsystem along with memory necessary to hold the control software to operate the sensor, to store the data collected, and to preprocess the data. Other processor/memory units could be integrated with T, T &C Power, Propulsion, and G,N &C systems. Another processor unit may function

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1E1

1. TECHNOLOGY REQUIREMENT (TITLE): Modular Architecture For Data Processing And Transfer Systems PAGE 2 OF 4

6. Rationale and Analysis: contd.

as a controller for the data bus which would interconnect the network of processors and memories. Once the distributed element and function concept is accepted, many other possibilities open up. New concepts in fault detection, tolerance, and correction become possible. Reliability and redundancy requirements can be approached differently. The total architecture of the data processing system becomes accessible and adaptable. Missions fly only what they require and as much as they require. Designers are not limited to some already designed system with its predetermined and frequently limited or restrictive capabilities.

It is the intent of this effort to maximize the use of commercially developed devices such as microprocessors, memories, and other LSI devices. The use of such commercial developments will yield significant cost and time savings. Unique LSI circuit development can be minimized. Support hardware and software, compilers, cross-assemblers, and documentation are already available. In addition there is a potentially large base of experienced designers, programmers, and users.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 1E1

1. TECHNOLOGY REQUIREMENT(TITLE): Modular Architecture For Data Processing And Transfer Systems — PAGE 3 OF 4

7. TECHNOLOGY OPTIONS:

a) A number of microprocessors with varying capabilities currently exist or are under development.
b) Virtually all semiconductor technologies are represented.
c) The nature and extent of the modularity and distribution of the architectural elements can and should be optimized.
d) LSI techniques are available for fabrication of optimal custom bus interfaces.

8. TECHNICAL PROBLEMS:

The problems resolve themselves into establishing a concept of the system and then developing the various elements including both hardware and software. There appears to be no technological barriers in implementing this approach.

9. POTENTIAL ALTERNATIVES:

The only recognized alternative is that of continuing the approach followed to date of increasingly larger and more complex central systems. Even here indications are that very large missions may require super data processing systems which may consist of a network of large processors of the SUM-C variety. This is viewed as a separate class of system and not an alternative to satisfying this need.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

RTOP 506-20-11 "Advanced digital data systems for deep space" JPL

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Continuing development of microprocessors using such technologies as CMOS and I^2L.
Development of advanced design mass and random memories.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1E1

1. TECHNOLOGY REQUIREMENT (TITLE): Modular Architecture For Data Processing And Transfer Systems PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Conceptual Design																			
2. Functional Design																			
3. System Development																			
4. System Integration																			
5. System Demonstration																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1G1

1. TECHNOLOGY REQUIREMENT (TITLE): Direct Broadcast/ Narrowcast Systems PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Direct Communication Technologies

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop a capacity to broadcast/ "narrowcast" multiple channels of programming to local users equipped with $1000 receivers by 1980 and esentially unmodified receivers by 1990.

4. CURRENT STATE OF ART: ATS6 has the capability of broadcasting single channels to approximately $3000-5000 receivers.

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

Shaped beams, efficient unenclosed high power tubes, improved power sources, beam switching, higher frequency components, local programming insertion techniques, possibly "frame-grabber" techniques (for narrowcasting), low sidelobes, video compression, etc. Would involve a technology demonstration satellite series incorporating increasingly capable versions of those technologies.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Shaped beams are required for shaping to political boundaries and for better spectrum management, such as frequency reuse (ditto low sidelobes). High power tubes are needed to permit cheaper ground stations to facilitate access to system. Similarly for high power sources. RTG's, etc. should be looked at for eclipse power although may not be justified. Beam switching may be desirable for narrowcasting applications to reach selected audiences. High frequencies may later be needed to obtain sufficient numbers of channels. Local program insertion may be difficult technology but needed for ultimate success of direct broadcast in U.S. and multi-language international applications. Frame grabber broadcast techniques might be adapted from CATV for narrowcasting. Video compression will effectively conserve bandwidth in multichannel situations, and will conserve power.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1G1

1. TECHNOLOGY REQUIREMENT(TITLE): Direct Broadcast/ Narrowcast Systems — PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

Many tradeoffs exist between specific user missions and involved technology. Also among various options. Main options relate to fact that ground vs. space cost tradeoffs exist. Optimizing the total system cost may make "entry cost" too high for users to have cheap access to system. Attention has been largely focused on the single area of large antenna "comsat" type systems so tradeoffs and techniques for personal communications, data collection, low-user-cost direct broadcast, etc. have not been well addressed. Examples of options include: use of multi-element low power arrays instead of high power tubes; need to consider video bandwidth array element development. Other examples: multiple spot beam vs. shaped dish vs. array; "framegrabber" vs. channel switching; video compression cost vs. high power satellite cost vs. spectrum wastage.

8. TECHNICAL PROBLEMS:

Most critical technical problem is low cost system/component/fabrication technology; if systems are not cheap, users will employ an alternative or forego communications. Next is spectrum conservation; spectrum is a more valuable resource than money--main answer is to go to higher frequencies where component sizes create problems of tolerance, fabrication difficulty, heat rejection, etc.

9. POTENTIAL ALTERNATIVES:

a) Millimeter vs. laser vs. microwave problems related to feasibility and spectrum availability.
b) High power plus reflector vs. low-power-element arrays.
c) Compression cost vs. power cost vs. user receiver cost for video
d) Interactive selection/switching vs. multiple channels
e) Low altitude vs. synchronous for navigation/position missions
f) Low cost mobile terminals vs. no. of users.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Intelsat V series for point-to-point communications--late 70's to 80's
CTS/ATS TV experiments, including video compression--mid 70's
GPS DOD Global Positiming Satellite
MARISAT

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

Power, navigation, data compression, on-board processing, attitude control structures.

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. 1G1

1. TECHNOLOGY REQUIREMENT (TITLE): Direct Broadcast/ Narrowcast Systems

PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Shaped beams/arrays																			
2. High Power Tubes/ Sources																			
3. Video Compression																			
4. High Frequency Components																			
5. Operational Video Techniques																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					Δ													
NUMBER OF LAUNCHES								1		1		1		1		1		5

14. REFERENCES:

a. Convair Payload Study
b. NAG Summer Study
c. Outlook for Space Exec. Summary
d. JPL Outlook for Space Tech. Forecast
e. High Power Tube Inputs from Alexovich-LeRC
f. NASA CR Tech. Implications of Information Transfer (LMSC)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1G1

1. TECHNOLOGY REQUIREMENT (TITLE): Direct Broadcast/ Narrowcast Systems

This definition includes a broad class of missions to demonstrate a variety of technologies leading to direct communications systems in the future. The objective of performing those missions is to recapture the national preeminence on communications technology with consequent favorable effects on national prestige, balance of payments, etc., as well as upon increasing the quality of social interactions underlying the national social structure. This broad class of missions would concentrate on those types of communications satellites essential to the future national well-being which are not currently (or in the foreseeable future) being attended to by the existing industrial structure. Recognizing that classical "trunking type" missions are being reasonably well-handled, at least in the near term by the existing institutions, the proposed missions would be concentrated on points-to-point missions such as DCP (data collection platform) data collection, and space data relay; upon point-to-points missions such as broadcasting or narrowcasting to local users; and ultimately, toward the year 2000, on particular enhancements of the points-to-points personal communications systems currently being more or less satisfactorily handled by the ubiquitous dial-up telephone system.

The technology of the present technology definition primarily emphasizes broadcast type missions. Another technology definition sheet will address data collection.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. IGI-A

1. TECHNOLOGY REQUIREMENT (TITLE): High Powered Microwave System, S Band — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Data Processing and Transfer

3. OBJECTIVE/ADVANCEMENT REQUIRED: To establish high power microwave tube technology for satellite solar power station.

4. CURRENT STATE OF ART: Microwave tubes have achieved necessary power levels terrestrially but not for use in space.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

This technology encompasses the design, fabrication, and testing of microwave tubes for the specialized needs of the SSPS. These tubes have power levels of 5 to 10kw in the case of crossed-field amplifiers; and from 50 to 100 kw for klystrons. In the interest of saving weight, open envelope tubes are advantageous. The technology of processing tubes in the hard vacuum of space must be developed.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Utilization of solar energy by means of a space satellite in geosynchronous orbit requires the technological development of specialized microwave tubes. These tubes must have a long life, cw operation, active phase and amplitude control, passive cooling capability, high efficiency, low noise, low cost, low weight, and they must operate at a frequency of 2.45 GHz to take advantage of an atmospheric window.

TO BE CARRIED TO LEVEL 10

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): High Powered Microwave System, S Band

7. TECHNOLOGY OPTIONS:

Two types of microwave tubes are feasible for the specialized requirements of the SSPS.

a) Cross-field amplifiers (CFA)
b) Klystrons

8. TECHNICAL PROBLEMS:

a) Identify primary sources of tube noise.
b) Develop active phase and amplitude control.
c) Activation of cathode in the hard vacuum environment of space.
d) Develop passive radiative cooling capability and designs.

9. POTENTIAL ALTERNATIVES:

Solid state microwave devices, so far, lack the power level required for this application.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Terrestrial demonstration of high efficiency transmission of microwave power to test the practicability of the SSPS concept.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

a) System problem of coupling large numbers (10^5 to 10^6) microwave tubes in arrays. The output signal of each tube must be controllable in phase and amplitude in order to properly launch microwave beam.
b) Structural integrity and assembly techniques in the space environment of arrays having dimensions measured in kilometers.

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): High Powered Microwave System, S Band PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Efficiency trade-off		X																	
2. Noise trade-off			X																
3. Terrestrial models				X	X	X	X	X											
4. Space models				X	X	X	X	X	X										
5.																			
APPLICATION																			
1. Design (Ph. C)										X	X								
2. Devl/Fab (Ph. D)												X	X	X	X	X			
3. Operations																	X	X	
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE									X								
NUMBER OF LAUNCHES								1								500	501

14. REFERENCES:

1) Fe[illegible] Study of a Satellite Solar Power Station NASA CR-2357, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. IGI-B

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave System, In Space Processing — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: To reduce the cost, weight, and improve the performance of microwave systems in the 1GHz to 100GHz range by using the unique properties of deep space to operate and process open envelope.

4. CURRENT STATE OF ART: A study has been completed that shows the advantages of tubes with open envelope in the area of efficiency, weight, and noise.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

The space shuttle in the sortie configuration will test the feasibility of:

a) Constructing a 2.45GHz, 6kw amplitron without a vacuum envelope and processing and operating the tube in space.
b) Terrestrial construction and processing of a 200watt, 12GHz TWT.

This tube will have a collector cover which will be removed in space.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☒ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) The purpose of this requirement is to establish a technology base for operating high power microwave tubes in space.
b) Designs, processing and fabrication must be investigated to take advantage of the properties of space to provide longer tube life and improved performance.
c) Exposing the tube parts to take advantage of deep space as a heat sink and the ultimate in vacuum environment is essential to the task.
d) The space shuttle in the sortie configuration will demonstrate the feasibility of the concept.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): High Power Microwave System, In Space Processing PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

a) Use of inefficient solid state devices in the low frequency ranges.

b) Use of larger encapsulated tubes with ion pumps.

c) Use of two tubes consecutively used in order to achieve long life system operation.

8. TECHNICAL PROBLEMS:

a) Higher temperature operation of some tube parts requires new fabrication techniques.
b) New processing techniques to be developed.
c) Vacuum environment on shuttle not completely defined.
d) Activation of cathode in 10^{-18} torr vacuum.

9. POTENTIAL ALTERNATIVES:

Terrestrially processed tubes with envelopes could be used, but these tubes would be heavier, larger, have a shorter life and poorer performance.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

A study program has been completed. A bread board model of a 200watt 12GHz system and a 6.0kw 2.45 system is planned to begin in fiscal 76. An engineering model of both systems will follow. The flight model of both systems is planned for the Shuttle in the fiscal years 80-82.

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a) High temperature brazing alloy techniques. 2000°C
b) Heat radiation techniques.
c) Development of unique Indium seal to be opened in space.
d) Use of rare earth magnetic materials.
e) Develop technology for millimeter wave high power systems.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave System, In Space Processing — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Brd. Expmt. D & F	X			X															
2. E. M. Expmt. D & F				X	X														
3. FH Expmt. D & F				X	X														
4. Space Tests					X		X												
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE									X									
NUMBER OF LAUNCHES																		

14. REFERENCES:

1) Final Report Contract NAS3-11536 Multistage Depressed Collector for Traveling Wave Tubes by Hughes Aircraft Co.

2) Final Report NASA 3-11532: Analytic Design of Space born-Axial Injection Crossed-Field Amplifiers.

3) NASA Contract NAS 3-18932

4) Raytheon Report-Microwave Power Transmission in the Satellite Solar Power Station System

5) Final Report, Contract NASA CR-2357 Feasibility Study of a Satellite Solar Power Station.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. IGI-C

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave Systems, Low Cost Ground Receiving Systems PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Data Processing and Transfer

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop low cost ground receiving systems for receiving wideband transmissions from broadcasting satellites at 43 and 86 GHz.

4. CURRENT STATE OF ART: Antenna, mixer, local oscillator, & detector techniques and approaches exist. Low cost approaches to system design and implementation need to be identified and developed. HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Ground receiving systems perform the functions of signal pickup (antenna) pre-amplification low noise frequency conversion, amplification, and detection. With some approaches, pre-amplification and/or frequency conversion may not be required. Key elements to low cost receivers are the microwave diodes and circuits used in the mixer and local oscillator and the uncooled parametric amplifiers for pre-amplification.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Devices and circuits exist to perform the required receiver functions. Effort is needed to identify those approaches that have potential for low-cost implementation. The available techniques need to be surveyed, cost/performance tradeoffs are required, low-cost designs need to be formulated. Without effort specifically directed toward low cost approaches, the design tendency is principally toward performance with only secondary (if any) effort directed toward cost objectives. A similar approach, design of low cost receivers prior to band use, was successful in producing low cost receivers for 2.6GHz and 12 GHz broadcasting satellite use.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT | NO.

1. TECHNOLOGY REQUIREMENT(TITLE): High Power Microwave Systems, Low Cost Ground Receiving Systems | PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Low noise performance available either via low noise mixer or pre-amplifier.

8. TECHNICAL PROBLEMS:

Implementing required functions at low cost, especially frequency conversion and pre-amplification.

9. POTENTIAL ALTERNATIVES:

High cost receiving systems which will inhibit use of the 43 and 86GHz satellite broadcast bands.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Continuing device development, and military receiver development in nearby frequency bands.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Solid state oscillators, mixer design techniques, low noise amplifiers, antenna designs.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave Systems, Low Cost Ground Receiving Systems. PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Receiving System Design			X																
2. Fabrication & Test				X	X														
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)					X														
2. Devl/Fab (Ph. D)						X													
3. Operations						X													
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE						X												
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT. NO. IGI-D

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave Amplifier, X-Band PAGE 1 OF 2

2. TECHNOLOGY CATEGORY: Data Processing and Transfer

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop and test an X-band microwave amplifier design for dual mode TWT to support deep space communications requirements.

4. CURRENT STATE OF ART: TWT's using multi-stage depressed collectors have been built at 12GHz which demonstrated efficiency of 50%.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The TWT would be a dual mode, 100/50W tapered helix amplifier augmented with a multi-stage depressed collector and spent beam refocusing system. The amplifier would operate at 8.3GHz and have an overall efficiency of 60%.

The dual mode operation can be easily accomplished by a gun with a non-intercepting grid. The operation would be optimized for the higher power level while the power conservation at the one half mode would be largely accomplished by the Lewis MDC combined with spent beam refocusing system.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Justification - The transmission of data from the near and very distant planets poses a requirement for the availability of TWT amplifiers with excellent performance in communication aspects with dual mode operation ability and with superior overall efficiency. The TWT amplifiers, with 100/50 watt dual mode ability is best suited to serve the needs of very distant or less distant transmission from planets, where the dual mode switching ability would greatly increase mission flexibility. While the planetary probe is in the vicinity of a planet, the TWT could use the higher power level for picture transmission at high data rates. The lower power level could then be used with lower data rates thereby making additional power available for science measurements.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): High Power Microwave Amplifier, X-Band PAGE 2 OF 2

7. TECHNOLOGY OPTIONS:

a) Increase prime power requirements to support a lesser efficient amplifier, or

b) limit data rate for picture transmission.

8. TECHNICAL PROBLEMS:

Design to achieve high overall efficiency and good phase and gain performance with a tapered helix structure.

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT NO. IGI-E

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave Systems, SHF Systems PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Data Processing and Transfer

3. OBJECTIVE/ADVANCEMENT REQUIRED: To establish high power rf system technology for space broadcast applications.

4. CURRENT STATE OF ART: Communications technology satellite (CTS), 200W TWT 12 GHz, 50% efficiency

HAS BEEN CARRIED TO LEVEL 4.

5. DESCRIPTION OF TECHNOLOGY

Analytical and experimental investigation of problems in high power (> 200W) space-borne microwave transfer systems, including rf power amplifiers, power processors and high power microwave waveguide chain components (switches, filters, diplexers, isolators etc.).

Critical parameters: Long life operation in space, minimum loss and distortion of signal, minimum weight and volume.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) Efficient use of assigned space broadcast bands.

b) High power required to reduce cost of earth stations and thus provide communications services to a wide variety of users.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): High Power Microwave Systems, SHF Systems

7. TECHNOLOGY OPTIONS:

a) Ground receiver noise temperature affects satellite rf power (direct dB relationship).

b) RF amplifier and power processor efficiency affects the DC power requirement (solar array size).

c) Number of simultaneous transmitter channels affects the transmitter power output (approximately 6dB backoff required for 2 channels).

8. TECHNICAL PROBLEMS:

a) RF losses increase with frequency
b) Multipactor breakdown
c) Thermal stability-small size of tuned elements
d) Production techniques - extreme tolerances
e) Efficiency is low - thermal problems

9. POTENTIAL ALTERNATIVES:

a) Power combining of several lower power sources as opposed to a single high power amplifier.
b) Low spacecraft output power will increase the ground receiver cost.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

None

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

None

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave Systems, SHF Systems PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Systems Tradeoffs	X	X																	
2. Component Design		X	X																
3. Thermal Design		X	X	X															
4. Component Tests				XX															
5. Prototype Test					X														
APPLICATION																			
1. Design (Ph. C)					XX														
2. Devl/Fab (Ph. D)						XX													
3. Operations							XX	X	X	X	X	X	X	X	X	X	X		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					X													
NUMBER OF LAUNCHES						1	1				1				1			4

14. REFERENCES:

a) Applications Technology Satellite Advances Mission Study, NASA-Lewis final report, NAS3-14360, July 1972.

b) Applications Technology Satellite Advanced Mission Study, NASA-Lewis final report, NAS3-14359, July 1972.

c) High Power Microwave Components for Space Communications Satellites, NASA-Lewis, Final report, NAS3-13727, Feb. 1972.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABOR   RY.
6. MODEL TESTED IN AIRCRAFT   IRONMENT.
7. MODEL TESTED IN SPACE   RONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. IGI-F

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Solid State Systems, UHF Band PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Data Processing and Transfer.

3. OBJECTIVE/ADVANCEMENT REQUIRED: establish high power RF system technology for space broadcast applications.

4. CURRENT STATE OF ART: 100W, 45% efficiency, 30 MHz bandwidth.

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Solid state UHF power amplifier with associated power conditioning and output circuit components (filters, isolators, power combiners, switches, diplexers, etc.) required for direct broadcast application such as disaster warning satellite.

satellite.	RF power output -	50 500W
	Bandwidth	20 MHz
	Gain	30dB

Critical parameters: Power output, efficiency, size, weight and long life.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) High RF output power required due to low cost ground receiver inside building (15 dB building attenuation, receiver NF) 7dB

b) Solid state devices and circuits increase lifetime, reliability of transmitter an offer opportunity to minimize size and weight of transmitter.

c) The technology program should culminate in the testing of a breadboard model on ground tests.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT | NO.

1. TECHNOLOGY REQUIREMENT(TITLE): High Power Solid State Systems, UHF Band | PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

Critical factors in the Disaster Warning System that affect the transmitter output power and satellite payload use:

(a) Efficiency of the transmitter affects the DC power requirements for the transmitter (linear relationship).
(b) Noise temperature of the ground receiver affects the required power output of the satellite transmitter (direct relationship in dB).
(c) Building attenuation directly affects the required transmitter output power (direct relationship in dB) antenna location, outside the building desirable.
(d) Number of simultaneous signals in the transmitter affects the output power available (limited by intermodulation signal level requirements) design assumed to be one carrier per transmitter. (Approximately 6dB back-off from maximum power output is required for 2 simultaneous signals.)
(e) Power output per transmitter affects the size and weight of the payload; the number of transmitters affects the size and weight of the payload.

8. TECHNICAL PROBLEMS:

State of the art in solid-state transmitters is: power up to 100W, 45% efficiency, 20MHz BW. In the power range of 100W to 430W, technical problems are: (1) thermal problems (transistor junction temperature = 125°C maximum); (2) large size and weight of the transmitter; (3) efficiency (loss of efficiency due to combining losses).

9. POTENTIAL ALTERNATIVES:

Cross-field amplifier can be used for higher power outputs; development of amplifier is required; cathode life appears to be a limiting factor in long life operation (5-7 years).
Power combining of many low power sources. The use of an outside antenna would reduce the attenuation from the present 15dB specification, thus lowering the transmitter power requirement. Cost of user receiver systems would increase.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

None

DEFINITION OF TECHNOLOGY REQUIREMENT	NO.

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Solid State Systems, UHF Band

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. System Tradeoffs	X	X																	
2. Transistor Selection		X																	
3. Thermal Design		XX	X																
4. Ampl. Ckt. Design		XX	X																
5. Breadboard Test			XX	X															
APPLICATION																			
1. Design (Ph. C)				X	X														
2. Devl/Fab (Ph. D)					X	XX													
3. Operations							X	X	X	X	X	X	X	X	X	X	X		
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				X														
NUMBER OF LAUNCHES							1	1			1					1		4

14. REFERENCES:

a) Disaster Warning Satellite Study, March 1971 NASA-Lewis

b) Disaster Warning System, NASA CR-134622, Final report, CSC

c) Disaster Warning Satellite Study Update, July 1975, NASA-Lewis

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT **NO.** ______

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Solid State Sy:* ms, UHF Band **PAGE 4 OF** 4

7. (Cont'd)

(f) Receiver bandwidth directly affects C/N of the receiver and thus the rf power output and DC power input requirements of the transmitter.

c-2

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. IGI-G

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave Systems, Millimeter Wave Systems

PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Data Processing and Transfer

3. OBJECTIVE/ADVANCEMENT REQUIRED: To establish high power rf systems technology for 41-43 and 84-86 GHz space applications.

4. CURRENT STATE OF ART: Microwave amplifiers and passive high power rf components have been developed for terrestrial applications. Approaches to space systems must be identified and developed. Space power processing systems have been developed with output powers of 500W at 11KV for CTS.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

High power millimeter wave rf system performs the functions of signal selection amplification to output rf powers of 100-200W. Passive components provide power amplifiers protection, harmonic filtering, signal multiplexing, and selective coupling. The power processing system converts prime electrical power to regulated levels necessary to support the power amplifier and provides the interface for remote command, control, and monitoring. Key elements of this technology are the microwave power amplifiers and the power processing system.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

To overcome spectral crowding, the World Administrative Radio Conference (WARC) in 1971 adopted world-wide exclusive allocations in the 40 and 80 GHz frequency bands for Broadcast Satellite Service, representing the first exclusive allocation for this purpose at any frequency. Having requested and received allocation, it is incumbent upon us to investigate the use of these bands at 41-43 and 84-86 GHz, which provide 4 GHz of bandwidth as compared to the current 500MHz of total TV bandwidth in use today. This capability will permit the transmission of a wide range of data for educational programming, medical conferencing, law enforcement and entertainment among other civil applications.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): High Power Microwave Systems, Millimeter Wave Systems

7. TECHNOLOGY OPTIONS:

Use of multiple low level amplifying devices with inherent low efficiency; 1-2 orders of magnitude below microwave amplifiers having overall efficiencies of 30-40%. Use of solid state, limited power devices resulting in extremely high ground systems cost.

8. TECHNICAL PROBLEMS:

The utilization of the 40 and 80GHz frequency bands for space application poses technology problems. Thermal component stress, which is proportional to the 5/2 power of frequency, will result in active and passive high power component development problems. Thermal power loading will approach 1000 W/cm^2 in the rf interaction structure. Cathode current density requirement will exceed 10A/cm^2. The solution to these problems at 40 GHz will require significant advances in rf structure and cathode technology. Beam refocusing efforts will be required in addition to advances in multistage depressed collector technology

(contd.)

9. POTENTIAL ALTERNATIVES:

High cost systems, with limited life and reliability, will inhibit the use of these bands.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

None

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave Systems, Millimeter Wave Systems

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. System Study	X	X																	
2. Amplifier Dev.	X	X	X	X	X	X	X	X	X										
3. Passive rf Comp. Investigation		X	X	X	X	X	X	X	X	X	X								
4. PPS Dev.				X	X	X	X	X	X	X	X	X							
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						X				X								
NUMBER OF LAUNCHES								1				1						2

14. REFERENCES:

"A Novel Axisymmetric Electrostatic Collector for Linear Microwave Tubes", H. Kosmahl NASA D-6093 Feb. 1971.

"A 240 Watt, 12 GHz Space Communication TWT with 56% Overall and 81% Collector Efficiency", H. Kosmahl, O. Sauseng and B. McNacy. IEEE-ED, Vol. Ed-20 Dec. 1973.

Mendel, J.T.; "Travelling Wave Tubes", Proc. IEEE Vol. 61, No. 3, March 1973 pp. 280-298.

Henry, J.F. "Some New Results With High Power Millimeter Wave Tubes", paper presented at 1964 WESCON Los Angeles, Aug. 25-28.

Okamoto, Tadashi, et.al.; "Millimeter Wave High Power Travelling Wave Tubes". Toshiba Review Vol. 26, No. 4, 1971 pp. 28-32.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.4

1. TECHNOLOGY REQUIREMENT (TITLE): High Power, High Efficiency Transmitter PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Special Devices

3. OBJECTIVE/ADVANCEMENT REQUIRED: Obtain power output in the range of 50 to 500 watts in the frequency band 620 to 790 MHz, transmitter characteristics to be: 45% efficiency, 30dB gain, 20 MHz bandwidth, minimum size and weight.

4. CURRENT STATE OF ART: 100W, 45% efficiency, 30MHz bandwidth, single channel centered at 790 MHz.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Direct broadcast CW operation, single channel operation such as required for the Disaster Warning Satellite (CN-54A).

Critical parameters are: power output, efficiency, size, weight, and long life.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Low cost ground receiver in a building (15 dB building attenuation); 58.6 dBW EIRP required for a 9.0 dB S/N ratio at the receiver; receiver noise temperature of 1100°K.
(b) Benefiting payload: CN-54A, Disaster Warning Satellite.
(c) Solid-state devices and circuits increase lifetime, reliability of transmitter and offer opportunity to minimize size and weight of transmitter.
(d) The technology program should culminate in the testing of a breadboard model on ground tests.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-5.4

1. TECHNOLOGY REQUIREMENT(TITLE): High Power, High Efficiency Transmitter PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

Critical factors in the Disaster Warning System that affect the transmitter output power and satellite payload use:

(a) Efficiency of the transmitter affects the DC power requirements for the transmitter (linear relationship).
(b) Noise temperature of the ground receiver affects the required power output of the satellite transmitter (direct relationship in dB).
(c) Building attenuation directly affects the required transmitter output power (direct relationship in dB); antenna location outside the building desirable.
(d) Number of simultaneous signals in the transmitter affects the output power available (limited by intermodulation signal level requirements); design assumed to be one carrier per transmitter. (Approximately 6 dB back-off from maximum power output is required for 2 simultaneous signals. (cont'd).

8. TECHNICAL PROBLEMS:

State of the art in solid-state transmitters is: power up to 100W, 45% efficiency, 20 MHz BW. In the power range of 100W to 430W, technical problems are: (1) thermal problems (transistor junction temperature = 125°C maximum); (2) large size and weight of the transmitter; (3) efficiency (loss of efficiency due to combining losses).

9. POTENTIAL ALTERNATIVES:

Cross-field amplifier can be used for higher power outputs; development of amplifier is required; cathode life appears to be a limiting factor in long life operation (5-7 years).

The use of an outside antenna would reduce the attenuation from the present 15 dB specification, thus lowering the transmitter power requirement. Cost of user receiver systems would increase.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Global Positioning Satellite Program - 1600 MHz transmitter being developed by North American Rockwell.
GE in-house program - VHF and 1600 MHz transmitters.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

None

7. TECHNOLOGY OPTIONS: (Continued)

(e) Power output per transmitter affects the size and weight of the payload; the number of transmitters affects the size and weight of the payload.

(f) Receiver bandwidth directly affects C/N of the receiver and thus the rf power output and DC power input requirements of the transmitter.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE-5.4

1. TECHNOLOGY REQUIREMENT (TITLE): High Power, High Efficiency Transmitter — PAGE 4 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE: High Power Amplifier (100-430W)

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. System Tradeoffs																			
2. Transistor Selection																			
3. Thermal Design																			
4. Ampl. Ckt. Design																			
5. Breadboard Test																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				4														
NUMBER OF LAUNCHES							1	1			1					1		4

14. REFERENCES:

(a) Telephone conversation with J. R. Ramler, NASA Lewis.
(b) Feasibility Study of Using Satellites for a Disaster Warning System, R-3015-2-1.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-1.9

1. TECHNOLOGY REQUIREMENT (TITLE): Large Microwave Antenna Arrays PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Maintain the required dimensional accuracy of large foldable antenna arrays in terms of flatness and phase-feed point dimensions.

4. CURRENT STATE OF ART: Antenna structure can be designed and manufactured to the required tolerances, but maintenance of the tolerances in the extreme thermal conditions of space is not in the SOA. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The subject advancement is representative of structural requirements for large (over 5m) foldable microwave antenna arrays for active and passive earth-sensing applications. Flatness requirements range from 1/4 to 1/20 wavelength. For instance, the ATL printed circuit array antenna which will support simultaneous measurements in altimetry, scatterometry and passive radiometry will require surface flatness during operation of less than 0.25 CM. During the Shuttle era, antenna lengths up to 30 meters long (Met. Radar Facility) are planned. They will be articulated or deployable, and will receive varying thermal flux contributions from the earth's albedo, the sun, and the Shuttle/Spacelab assembly.

Foldable antenna arrays, up to 30 m. long have not been built to date. A 14 meter long printed phase array is being designed for SEASAT. Although flatness tolerances of 0.25 CM over a 25 meter span are well within current manufacturing capabilities, the maintenance of these tolerance limits under the expected space thermal conditions is not within the state of the art.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☒ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) The required dimensional tolerance of antenna arrays will be based on operating frequencies ranging up to 100 GHz and the criteria of 1/4 to 1/20 wavelength contour accuracy. The optimum frequency upon which the design will be based will consider the required altitude and radiometric measurement accuracy and degree of weather penetration.

(b) This technology advancement specifically supports: the Slotted Waveguide Antenna for Payload No. ST- 22S (ATL); the Shuttle Imaging Microwave System, EO-05S; Multifrequency Radar Land Imagery, OP-02S; Multifrequency Dual Polarized Microwave Radiometry, OP-03S; and the Millimeter Wave Experiment.

(c) This advancement will be instrumental in attaining altitude measurements with less than one meter error for averaging times of ten seconds, land and ocean imaging, microwave soundings of the atmosphere and other earth observation applications.

(d) Structural models of the antenna array should be tested in simulated thermal vacuum conditions.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GE-1.9

1. **TECHNOLOGY REQUIREMENT(TITLE):** Large Microwave Antenna Arrays PAGE 2 OF 3

7. **TECHNOLOGY OPTIONS:**

The 1/4 to 1/20 wavelength flatness criterion will be relaxed, in some instances, depending on the allowable degree of measurement degradation. The antenna dimensional tolerance will significantly affect microwave beamwidth, sidelobes, and system efficiency. Methods of actively adjusting the position of individual antenna segments to compensate for deflecting influences, such as thermal gradients or inertial loads are theoretically possible, but may introduce undue complexity and program cost.

8. **TECHNICAL PROBLEMS:**

Thermally induced deflections must be minimized through proper material selection and structure design. The hinge mechanism must be properly indexed to permit proper parallelism between antenna segments and its elements after antenna deployment (unfolding). Special test procedures must be developed to simulate zero-g for pattern measurements and thermal distortion measurements. Erectable antenna structures 10 to 30 meters long, built for maximum weight saving, will be subject to serious distortion forces due to gravity during ground testing.

9. **POTENTIAL ALTERNATIVES:**

Altimetry measurements will be feasible through use of a smaller array or parabolic antenna, as indicated in DTR No. GE-4.4. However, the high resolution microwave radiometry and imaging applications will require a large array.

10. **PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:**

a) RTOP W74-70492 Earth Observations Radar Workshop
b) RTOP W74-70274 Structural-Thermal-Optical Program
c) Additional technology program emphasis will be required to insure availability of the required antenna technology early in the Shuttle Program.

EXPECTED UNPERTURBED LEVEL 3

11. **RELATED TECHNOLOGY REQUIREMENTS:**

The development of the subject antenna technology must be done in conjunction with the analysis and advancements in microwave systems for altimetry, scatterometry, radar imaging, and passive microwave radiometry. The advances in holographic microwave techniques will be relevant to the subject requirement, since the dimensional tolerances on the antennas will be more stringent.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GE-1.9

1. TECHNOLOGY REQUIREMENT (TITLE): Large Microwave Antenna Arrays — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Thermal/Structural Anal.																			
2. Material Selection																			
3. Range Tests of Prototype																			
4. Space Qualification																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				4														
NUMBER OF LAUNCHES						5	5	4	4	4	3	4	5	4	6	5	4	53

14. REFERENCES:

1. Study of Shuttle Compatible Advanced Technology Laboratory ATL. TM-X-2813
2. Shuttle Imaging Microwave System (SIMS), Perspectives and Objectives, by Dr. J. Waters, JPL, January 22, 1974.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT **NO.** ______

1. TECHNOLOGY REQUIREMENT (TITLE): High Power Microwave Systems, Millimeter Wave Systems **PAGE** 4 **OF** 4

8. (Cont'd) to control widely divergent beams resulting from high space charge forces. The power processing system required to support rf power amplifiers in this frequency range must provide regulated output powers up to 800W with voltages of 25kv to 40kv. In addition, energy storage must be limited to preclude catastrophic failure due to an internal arc. This represents a significant advance in space power system technology.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.8

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Optics Experimental Techniques for Lasers; Communication Fineness And Stability Of Alignment; Enable Manual Access As Well As Automatic And Manual Adjustment. PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Collectors

3. OBJECTIVE/ADVANCEMENT REQUIRED: Alignment of multiple mirrors of optical system is desired within 0.04 arc second (may be mitigated for optical bench by choice of mirrors) to minimize wavefront distortion, avoid spoiling coherence, and enable tracking. Tracking of gimbaled laser telescope will be good to about 1 arc second after initial acquisition search.

4. CURRENT STATE OF ART: Optically flat mirrors (even half silvered for beam splitting) and two axis mirror mounts manually adjustable up to 0.1 arc sec exist; however, neither adjustments for long optical trains nor the breadboard philosophy for laser experimentation have been proven yet. HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY Modulated laser beams at 10.6, 1.06, 0.53μm are used as carriers in a laser communication system. For experimenters to have access to the lasers and receiving circuitry, systems of mirrors are used to route received and transmitted beams to an optical telescope that is used for projecting and receiving the signals. To avoid damage to mirrors the outgoing laser beams are expanded to distribute laser energy over a greater reflection area. All the optics are to be mounted in a stable structure. Some of the mirrors are fixed but manually adjustable; some are on two axis mounts driven by error signals via analog or digital computing circuits to compensate for Space Lab or orbital vehicle motions as well as tracking errors. In practice, small optical mirrors cannot maintain beam coherence equivalent to 0.04 arc sec (Airy disc size is about 1 arc sec at wavelengths shown). However, as has been demonstrated by many autocollimators, angular detection devices track either the centroid or preferably the edges of a reflected image of a small mirror which may be blurred by diffraction and aberrations with an accuracy of 0.04 to 0.06 arc seconds. "Cat's Eye" type reflectors need to be researched to minimize need for sub-arcsecond alignment.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a. Although most of the optical system components for receiving and transmitting the laser communication to and from a Space Shuttle Orbiter payload are available, logic programming and servo system techniques need to be developed to enable integration of components.

b. The techniques are needed to implement CN-05-S, Laser Communication Experiment (MSFC version). An additional laser experiment proposed by GSFC with a new CN-XX-S number can be mounted outside the Spacelab cabin on the pallet. It is not accessible for manual experimentation during flight. However, the optical beam alignment and transfer techniques may be applicable to all payloads involving optical referencing, tracking, or pointing, where very good correlation and alignment are needed.

c. The techniques will enable development of techniques for proper detection and translation of laser signals from ground to space and space to ground. A later GSFC experiment will apply lessons learned toward development and test of practical laser communications equipment.

d. The technology requirement is satisfied when a similar optical system functions successfully in space.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.8

1. TECHNOLOGY REQUIREMENT(TITLE): VIS-IR Optics Experimental Techniques For Lasers; Communications Fineness And Stability Of Alignment; Enable Manual Access As Well As Automatic And Manual Adjustment. PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

A preliminary review of the current state of the art indicates that the up-link and down-link optical transmission trains can be corrected by servoed beam deflectors driven by error signals obtained from tracking detectors. However, no existing system for as many optical elements exist. The most critical beam deflectors are those coupling the gimbaled telescope to the internal laser and detector optics. Tracking capability will depend largely on the accuracy and stability of the optics train used to track the incoming laser signals. Use of a stable optical base and strategic layout of optical trains will reduce the number of servoed deflectors to a minimum.

A major trade exists as to whether a multiple carrier laser communication experiment in breadboard (optical bench) form or the finished operational form is flown. Plane parallel plates in divergent or convergent optical space can provide up to 100:1 advantage in beam angular adjustments.

8. TECHNICAL PROBLEMS:

a. Optical path extends from pallet in shuttle orbiter to pressurized module and is subject to large deflections and distortions.
b. Use of a number of movable mirrors in passing the beam through a multiaxis mount as well as the beam deflectors requires a systematic allocation of corrections in each axis of each deflector.
c. Tracking pointing needs to be accomplished to within a fraction of a beamwidth (0.1 arc sec for 1 arc sec beam) simultaneously with alignment of laser signal optical trains; interactions may occur.

9. POTENTIAL ALTERNATIVES:

a. A computer controlled alignment system using auxiliary corner reflectors or fiducial marks on each servoed mirror might enable balanced correction of errors in alignment of mirrors.
b. A more reliable laser communicator unit mounted on standard gimbals (Instrument Pointing System) can be used in later communication experiments. It avoids laser beam tracking through windows and on optical bench but is not accessible for human manipulation.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

a. W74-70344 (502-03-11) Optical Communication Research, GSFC, H. H. Plotkin, (301) 982-6171.
b. Communication Exp. Definition, TRW Report DR-MA-04, pages 9-1 through 9-19, Appendix A, 9A-1 through 9A-15 under study from MSFC (C. Quantock).

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

a. Telescope pointing to 0.1 seconds (beam adjustments to sub-arc seconds can be accomplished by use of plane parallel plates in divergent or convergent optical space to obtain a lever effect where the actual mirror angle can be adjusted only with a precision of several arc seconds).
b. Tracker and alignment detector errors less than 0.1 arc seconds to minimize accumulative errors of several loops.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. C-1.8

1. TECHNOLOGY REQUIREMENT (TITLE): VIS-IR Optics Experimental Techniques For Lasers; Communication Fineness And Stability Of Alignment; Enable Manual Access As Well As Automatic And Manual Adjustment. PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Parametric Analysis	—	—																	
2. Comm. Breadboard			—	—															
3. Test & Evaluation				—	—														
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)					—	—													
2. Devl/Fab (Ph. D)						—	—												
3. Operations								●	●	●			●	●	●				
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					T													
NUMBER OF LAUNCHES								1	1	1			1	1	1			6

14. REFERENCES:

a. Definition of Experiments and Instruments for a Communication/Navigation Research Laboratory, Vol. II, Experiment Selection, Study Report DR-MA-04, May 1972, TRW, pages 9-1 thru 9-19, Appendix A pages 9A-1 thru 9A-15.

b. Summarized NASA Payload Descriptions, Sortie Payloads, Level A Data, NASA PD, July 1974.

c. Preliminary Payload Descriptions, Volume II, Sortie Payloads, Level B Data, NASA, July 1974.

d. Ltr. from Robert T. Martin of Barnes Engineering Company to H. Ikerd, 27 Dec. 1975.

Legend

T = Technology

● = Sortie Operations

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. IG2

1. TECHNOLOGY REQUIREMENT (TITLE): DCP (Data Collection Platform) Collection Technology — PAGE 1 OF 5

2. TECHNOLOGY CATEGORY: ____________________

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop continuously available system for collecting data from DCP's - together with low cost DCP technology.

4. CURRENT STATE OF ART: Perhaps several hundred DCP's work with SMS and Nimbus to transmit data.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Signals from DCP's are received by satellite, transmitted to ground and used to compute position information if needed. On ground, data is disseminated to users of each class of DCP. Number of DCP's may be 50,000 in future. Some stations to be interrogated. Others send data at random times. Data rate of station may vary from 100-100,000 m'ts per pass. Stations to be located within 1 mile at first, then 0.1 mile. Sensitive receivers, and high EIRP/cost DCP's needed. Moderate downlink capacity needed. Later version may have ability to transmit data directly to users(?).
Principal need is to provide service continuously and reliably so that user community can develop confidence and increase in size.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:
Many disciplines, in addition to (or instead of) remotely served data, need data from in site, or in place sensors. Examples are tiltmeters for earthquake prediction, timber moisture indicators for forest fire prediction, multifunction ocean buoys, weather balloons, hydrological stream gages, valcendogy temperature and seismic sensors, etc. Many of these devices must be emplaced in remote locations where they must operate automatically for long periods of time. These disciplines are becoming increasingly important as we approach the era of global resource/phenomenon management. Conventional communication means are wholly inadequate to provide timely data collection from these platforms. Consequently, convenient means for collecting data from such systems must be developed. Current systems are designed with such users essentially as an afterthought to be main mission and so have not been sufficient to accumulate large user groups. In the future there will be a need for a continuous reliable data collection service to help build up a user community. Many potential users are turned away by the short term nature of the experiments.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO.

1. TECHNOLOGY REQUIREMENT(TITLE): DCP Collection Technology PAGE 2 OF 5

7. TECHNOLOGY OPTIONS:

Low altitude vs. synchronous gives timeliness and synoptic view but makes radiolocation and low cost DCPs more difficult.

Future DCP collection satellites may need to be fairly wideband but not a problem outside state of art. May need on-board processing at a moderate level to sort out signals and later may need capability to broadcast signals to users directly (may relay signal to a data dissemination satellite).

Synchronous version will require interferometry to determine position of mobile DCP's.

Low cost, multipurpose DCP transmitter/memory/multiplexer/long-life power supplies.

8. TECHNICAL PROBLEMS:

The only serious problem will be the development of low cost, high power DCP transmitters antennas. In the case of balloons, low weight, jet engine-ingestable. In the case of buoys, corrosion resistant. These are user problems but will be facilitated if DCP collection satellite, designed for users specifically and operated reliably and continuously, is developed.

9. POTENTIAL ALTERNATIVES:

Current alternatives include collection of data tapes by horseback, hiking, snowmobiles, buoy-tender ships, etc. Such means are costly and sacrifice timeliness of data.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

SMS/GOES
ATS6 (?)
Nimbus

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

On-board data processing, navigation/position determination, possibly wideband data relay, earth resources data dissemination.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO.

1. TECHNOLOGY REQUIREMENT (TITLE): DCP Collection Technology —

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Low cost DCP XMTR																			
2. Sensitive receivers																			
3. On-board Processors																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE					4													
NUMBER OF LAUNCHES								1			1			1			1	4

14. REFERENCES:

NAS Summer Study
Hughes A/C Contacts
Data Collection Platform User Document (See Workshop library for doc. no.)

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

Insitu sensors, or DCP's (Data Collection Platforms) hold very great promise, particularly for augmenting remote sensing systems. Probably the best compendium on the subject of DCP's is the "Satellite Data Collection User Requirements Workshop"(Draft Final Report), edited by E. Wolff, et al. at GSFC on May 21, 1975.

This report outlines literally hundreds of applications for DCPs. In Agriculture they can be used to collect crop forecast data and to calibrate remote sensors; in Biology for censusing, population dynamics, and physiological monitoring; in Ecology for effluent monitoring, climate monitoring, etc; Geology can use them for iceberg tracking and statusing of inaccessible instruments; Hydrology can use them to obtain river and precipitation data for a host of hazard alleviation activities such as flood warning and control; Meteorology can use them to provide data in a form suitable for automatic weather analysis techniques; Oceanography can use them for surface truth to calibrate remote sensors, for weather forecasting and climatology research; Search and Rescue can use them for locating boats, planes, campers, etc. who are lost or otherwise in trouble; and Transportation can use them for monitoring the location of hazardous or valuable shipments, maritime position location, etc.

Satellite Data Collection is basically a technique used to monitor unattended sensory platforms via telecommunications. It should be distinguished carefully from remote sensing, in which the sensor is remote from the surface characteristics being sensed. Large numbers of platforms are characteristically used, possibly hundreds to thousands, so the cost of each platform must be kept low. The data rates involved are typically not high - on the order of 100 to 1000 bits per range-rates or doppler, navigation tones, etc. Either low earth

(cont'd)

orbits or geostationary orbits may be used depending on the power capability of the stations.

The first satellite data collection system was OPLE (Omega Position Location Equipment) using synchronous satellites (ATS 1 or 3) in the early 60's, to locate and collect data from balloons, buoys, mobile vehicles, and aircraft (a version was modified for search and rescue).

In the mid 60's the IRLS (Interrogation, Recording and Location System) used low orbits (Numbus 3 and 4) to collect data from balloons, buoys, and wild-life beacons. EOLE was a French system based on the same principle that was used in the early 70's.

Many users have expressed an interest in direct readout of data to local user receivers instead of regional receiving and processing. In the future there will be a need for greater precision of location, higher data rate systems, and higher station capacities; presently the capacity is 1-5 km accuracy and 200 stations simultaneously in view. The most important technology development is undoubtedly lower cost longer lived platforms. There is much need for a dedicated DCP collection satellite. GSFC is planning a feasibility study for a dedicated low altitude Datasat to perform this function -- continuity will be very important.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1G3

1. TECHNOLOGY REQUIREMENT (TITLE): Trunking Telephony Technology PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Data Process Transfer

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop technology to permit maximum cost-effective utilization of limited orbital spaces and spectrum in providing communication links to hundreds / thousands of ground stations.

4. CURRENT STATE OF ART: Intelsat Consortium and a few Domestic Satellite companies are providing thousands of channels to about a hundred stations.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Multiple beam forming; Pencil (1^{o}) beams to individual stations; digital speech interpolation (DSI); digital television; intersatellite laser links; instantaneous load-assigned switching; demand assigned multiple access technique multibeam antenna feeds; lens arrays; electronic phased arrays; cheap transportable ground antennas; simple, reliable on-board computing for demand-assigned beam switching; low current switches; efficient forward error correction; smaller components; highly linear broadband amplifiers.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Trunking communication is highly developed but demand is growing rapidly. Orbital slots and spectrum are limited. Technology is required that will permit packing as much communications capacity as possible into each orbital slot within the total bandwidth permitted. The future will go to the digital link, so digital techniques are extremely important. Multiple beams and multiple access permit efficient frequency reuse. Intersatellite links permit multiple satellites to be used conjointly in a frequency saving manner. Lens arrays, electronic arrays, multiple feeds used for instantaneous beam forming. Cheap ground antennas permit easy user access and flexibility in network forming. Forward error-correction and coding will make digital interconnection of computers and other digital transmission uses. Highly linear amplifiers will permit return to more efficient FM. DSI will permit more efficient lower cost voice.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1G3

1. TECHNOLOGY REQUIREMENT(TITLE): Trunking And Telephony Technology PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

Arrays vs. multifeeds
Laser vs. millimeter intersatellite links
AM vs. FM modulation (given linear amplifier)
Tradeoff on minimum supportable ground antenna
On-board vs. on-ground beamswitching computers
Various types of multiple access
Use of DSI or not (peak-load voice quality)
Many tradeoffs on cross-polarization, multiple-interconnected satellites, beam switching, and other orbital slot utilization techniques.
Shuttle vs. standard launch.

8. TECHNICAL PROBLEMS:

3 axis stabilization required for larger satellites greater complexity, reliability problems (potentially)
Digital transmission requires much development
Many multiple access tradeoffs need to be explored
As demand increased existing spectrum/orbits will become increasingly inadequate calling for even more sophisticated technology.

9. POTENTIAL ALTERNATIVES:

Ground communication: undersea cables; light pipes, millimeter communication; microwave towers; hard wires. Note that in the future in the U.S. these alternative means will be increasingly used for trunking between large cities with satellites used for "thin route" and "exotic" communication. Overseas, trunking will continue to use satellites.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Intelsat 5, Marisat, planned domestic satellites will develop many of those technologies to some extent. Much further development will be required to meet the expected demand.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Attitude control; structures; data processing; electronic components; antenna design; user terminals.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 1G3

1. TECHNOLOGY REQUIREMENT (TITLE): Trunking And Telephony Technology

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Multiple beams/switching (pencil beams)																			
2. Digital Television																			
3. All Digital Systems																			
4. DSI																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES								1	1	1	1	1		1		1		7

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT **NO.** 1G3

1. TECHNOLOGY REQUIREMENT (TITLE): Trunking And Telephony Technology **PAGE** 4 **OF** 4

Communications represent the connecting links or "glue" holding society together. Satellites represent a wholly new way, independent of distance, to perform this function. Many wholly new communication modes (such as international television) are now possible. Communication is growing at rates typified by 4 year doubling periods - even higher for totally new services. Unfortunately the total spectrum is limited, as are the number of orbital positions. Therefore it is critical now, and will become much more critical in the future, to make optimal use of frequencies and orbital positions. The technologies described here are almost totally devoted to this end.

To the extent that these technologies are developed, communications satellites will remain a strong competitor to the alternative "terrestrial" technologies by keeping up with the demand in a cost-effective way. Another dimension of the problem represented by these technologies is that of digital communications. Digital television will permit doubling the amount of TV coming through a transponder. By 1985 or 1990 over half of the communications in the national telephone network will be digital. Communications satellites must prepare for this flood of digital data.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1G4

1. TECHNOLOGY REQUIREMENT (TITLE): Spectrum Monitoring Technology (RFI) PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Data Processing and Transfer

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop components, designs, and operational techniques for performing communication experiments (with emphasis on propagation experiments and spectrum monitoring).

4. CURRENT STATE OF ART: Some laser experiments on manned missions; DOD has "ELINT" and "FERRET" capability in space; NSA and FCC monitoring on ground.

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

Large, multibeam, wideband (or channelized) array or other antenna arrangment for scanning at least U.S.Z.I. from orbit to map usage of spectrum by ground stations, microwave towers, satellites, mobile transmitters and base stations, etc.. Array will be deployable. Synchronous orbit over U.S.. Very sensitive receivers and cool front ends. Relay capability to ground (high data rate) or to manned orbital communications laboratory in low earth orbit. Should be able to scan frequencies up to at least 10 GH_3 in no greater than 100 H_3 windows and locate signal sources down to 5 km on earth at 5-band (corresponding decrease at lower frequencies).

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Usage of the spectrum is already extensive (millions of transmitters in U.S.Z.I.) and growing at up to 20% per year. The spectrum, although theoretically unlimited, is limited above by component tolerances, power levels available, propagation losses, rainfall attenuation, etc.. Therefore there is a need for breakthroughs in the management of this precious public resource. To manage such a finite, but instantaneously renewable, resource will require dynamic and comprehensive surveillance of spectrum usage at any given time. This is currently done on a limited scale using signal monitoring vans; a synoptic view will require satellite monitoring techniques. The requirement for large antennaes derives from need to locate radio sources fairly accurately. High sensitivity/low noise derives from desire to pick up faintest possible signals. It is recognized that very faint signals will be beyond the limits of the system due to high space losses. System may be invaluable in resolving space-to-ground and ground-to-space interference problems.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1G4

1. TECHNOLOGY REQUIREMENT(TITLE): Spectrum Monitoring Technology PAGE 2 OF 4

7 TECHNOLOGY OPTIONS:

Low altitude with reduced coverage and fainter signals picked up vs. synchronous
Large arrays vs. synthetic aperture and processing techniques
Use as free flyer with manned orbital lab or as a manned experiment
Cryogenic front end
On-board storage with period readout to manned lab vs. relay link vs. on-board processing and transmit results

8. TECHNICAL PROBLEMS:

There will be a need for continuing development of lower temperature, more sensitive receivers and better arrays to reach ever weaker signals. Tradeoff studies will be needed to confirm concept and verify that signal coverage will be adequate. May be problems with high data rate readout or on-board processor. A serious problem will be finding room on the spacecraft for the wide variety and large number of antennas, interferometer, and instruments on the earth side of a vehicle.

9. POTENTIAL ALTERNATIVES:

Alternatives would include (1) not monitoring the spectrum and taking the consequences of lack of management (already becoming evident) or (2) using large numbers of aircraft and monitoring vans equipped with sensitive receiving equipment (which will never provide a synoptic map).

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Nothing is planned for the U.S. in this area in the civilian sector. The DOD will probably be continuing its ground, aircraft, and spacecraft-based collection of electronic data over foreign countries.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Altitude control, structures, station keeping, possibly electric propulsion (for attaining synchronous orbit), on-board data processing.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 164

1. TECHNOLOGY REQUIREMENT (TITLE): Spectrum Monitoring Technology PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Antenna																			
2. Receivers																			
3. On-board Processor																			
4. Relay																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES										1					1			2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1G4

1. TECHNOLOGY REQUIREMENT (TITLE): Spectrum Monitoring Technology PAGE 4 OF 4

Section 6 has outlined the rationale for this technology, and the other sections have briefly defined the technology. The mechanism for benefiting the U.S. is that of conserving and managing a valuable, limited resource, so that the maximum value comes from its use. Procedures and institutions for spectrum management now abound, but they are hampered by lack of precise knowledge as to the ways in which the spectrum is being used or abused. In the first phase, the proposed system would provide such knowledge in a more or less static sense. In later use it would pave the way for dynamic, almost real time management of the spectrum. Perhaps the first launch might be a low altitude 28.5° version followed 5 years later by a synchronous version. The spacecraft will be essentially a large antenna farm in orbit with a highly sensitive receiver array, possibly some on-board data processing (not present in some options) and a high capacity data relay either to the ground or to a manned orbiting lab.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2A1

1. TECHNOLOGY REQUIREMENT (TITLE): Coordination Of NASA Research And Development In Computer And Information Sciences PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop knowledge and approaches that will lead to a significant (10:1) reduction in agency costs for information management (per information unit, per function) by 1985.

4. CURRENT STATE OF ART: Total NASA expenditures for automated data processing are rising. Much effort within the agency is devoted to increasing efficiency and decreasing costs, but it is not coordinated.

HAS BEEN CARRIED TO LEVEL NA

5. DESCRIPTION OF TECHNOLOGY

The technology addressed in this requirement is the coordinated planning and review of agency-wide activities devoted to the development of computer resources and to their application. Included within their scope are:

a) Software generation and human-machine interaction: The means by which computer-based tools are developed and applied.
b) Software management: The means by which the development of software is planned, its cost estimated and measured, and its production controlled.
c) Functional algorithms: The software tools that perform information processing tasks in response to human intentions and requirements.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

As NASA undertakes more difficult missions, increasing reliance is being placed on computers to handle the steadily rising information-management requirements. Expenditures for the procurement of data processing equipment and for software grow year by year and absorb an increasing share of the total NASA budget. All centers are engaged in a variety of computer-related activities - payroll accounting, flight software development, information and computer science research, algorithm design, and others. There is concern throughout the agency for lowering software costs, reducing duplication of effort, and sharing expertise and experience, but there is no single office with responsibility for directing and coordinating the results of such efforts for the agency as a whole. Such an office should be created to bring about the following objectives: 1) Review all agency computer related tasks and activities; 2) Maintain records of ADPE expenditures and related efforts; 3) Secure the development of a coordinated plan for research as development in computer and information science in fields of importance to future NASA goals; 4) promote the lowering of cost through selective standardization, sharing of facilities, software, and expertise and research. The savings in computer related costs should more than pay the expenses of such an office.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2A1

1. TECHNOLOGY REQUIREMENT(TITLE): Coordination Of NASA Research And Development In Computer And Information Science   PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

a) Set up a headquarters program office for overall data management coordination.
b) Select lead centers for data management for each major NASA program office, these to report to a coordinating agent at headquarters.
c) Assign responsibility for coordinating appropriate aspects of computer and information science efforts to be unified by a responsible associate administrator.

8. TECHNICAL PROBLEMS:

Creating the appropriate management structure.

9. POTENTIAL ALTERNATIVES:

Postpone action until OMB initiative precipitates such steps or are proposed here.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Coordination of data management efforts within OA by MSFC.

EXPECTED UNPERTURBED LEVEL NA

11. RELATED TECHNOLOGY REQUIREMENTS:

NASA Network for Computer Facility and Software Sharing
Software Management
Software generation and human-machine interaction
Functional algorithm development

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2A1

1. TECHNOLOGY REQUIREMENT (TITLE): Coordination Of NASA Research And Development In Computer And Information Sciences

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Study NASA computer efforts																			
2. Examine organizational alternatives																			
3. Decision on implementation				∇															
4. Phased Changes																			
5. Change Complete						∇													
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE						∇											
NUMBER OF LAUNCHES	NA																

14. REFERENCES:

Outlook for Space

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2A2

1. TECHNOLOGY REQUIREMENT (TITLE): Software Generation And Human-Machine Interaction PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop methods for programming and utilization of computers that will contribute to reducing overall NASA software costs (per Unit of output per activity) by a factor of 10 by 1985.

4. CURRENT STATE OF ART: A variety of programming tools and devices to facilitate human-machine interaction exist. The programming and use of computers still remains the domain of the computer software specialist.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Two highly related but separable functions are included in this requirement:

a) Software Generation: Techniques for designing and developing computer programs, testing them, verifying their correctness, and maintaining them. Contributing disciplines include higher-order languages, automated programming and program verification, operating systems, compilers and assemblers, data system architecture, structured programming, and others.

b) Human-Machine Interaction: Techniques for interfacing human beings and machines in a congenial and comfortable way so that they can cooperate to do work. Contributing disciplines include human factors engineering, time-sharing systems, interpretive compilers, display, natural language understanding and generation, interactive systems, and others.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Two major obstacles impede the transfer of human information processing functions (from sorting and computation to language translation) to computers. One is the conversion of information requirements into sets of instructions that can be executed by the machine; that is, programming. The other is the process of interactions between humans and machines that leads to a desired processing result (which may be a program stored in the machine). Both obstacles reflect the facts that information processing is, by and large, a complex and little understood activity of human thought, and that the capabilities of present machines are limited. Thus in the cooperation of humans and machines to do work, the major burden falls on the humans. Since computers are fast and their cost is falling, the cost of using machines is predominantly the cost of human labor to prepare or instruct them. To lower these costs means moving more responsibility to machines, thereby increasing the productivity of the human position of the effort.

A broad attack is being made throughout the world, especially in the U.S., on the problems described above. Much work is done within NASA. It is not done, however, as the result of a philosophy and plan of attack developed by the agency as a whole. Among the issues that merit careful and thorough consideration by knowledgeable software experts within NASA are these:

(continued on page 1a)

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2A2

1. TECHNOLOGY REQUIREMENT (TITLE): Software Generation And Human-Machine Interaction   PAGE 1a OF 4

a) In what fields can success in research and development efforts yield the greatest benefits to the agency?
b) In what fields does NASA have the talent or expertise to make a significant contribution to the solution of basic problems?
c) What should be the size of NASA's efforts devoted to the reduction of software costs in relation to total software expenditures?
d) Are there advantages to be gained by combining and coordinating related research and development efforts at different centers?
e) Are there fields in which NASA should initiate work (in-house or elsewhere) because of the potential cost reduction benefits?
f) Are the results of successful research and development efforts properly documented and disseminated within the agency?

A comprehensive approach that addresses these questions can do much to insure that existing efforts are mutually supporting and productive, that the addition (or deletion) of efforts is based on a sound rationale, and that the size of the total program is in proportion to the size and value of the results sought.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 2A2

1. TECHNOLOGY REQUIREMENT(TITLE): Software Generation And Human-Machine Interaction — PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

a) The content of present agency programs related to this requirement should be carefully reviewed and a plan prepared for integrating them.
b) Studies should be conducted of the status of work in a number of areas, and assessments made of the potential benefits of conducting such work within NASA or applying existing knowledge. Among such areas, these are suggested:
1) structured programming; 2) automated programming and program verification; 3) microprogramming (for hardware emulation); 4) display techniques; 5) human factors in information transfer; 6) natural language understanding and generation; 7) speech synthesis; 8) interactive systems.

8. TECHNICAL PROBLEMS:

a) Developing a comprehensive perspective on the variety of work conducted within NASA that relates to the requirement
b) Creating a coordinated program that provides existing tasks with cohesiveness and direction without stifling imaginative creative efforts by individuals presently working within NASA

9. POTENTIAL ALTERNATIVES:

Allowing existing offices to fashion programs for software research and development that meet their own needs.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

OAST has successfully coordinated microelectronics development at LaRC, MSFC, and JPL into a "Predictable Long-life Components" program.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

NASA Network for Computer Facility and Software Sharing
Coordination of NASA Research and Development in Computer and Information Sciences
Software Management
Functional Algorithm Development

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2A2

1. TECHNOLOGY REQUIREMENT (TITLE): Software Generation And Human-Machine Interaction

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Survey agency R & D in relevant areas																			
2. Study and consultation; Software workshops																			
3. Program Planning																			
4. Phased Program Shaping																			
5. Balanced, Goal-Oriented Program									V										
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE									V									
NUMBER OF LAUNCHES																		

14. REFERENCES:

A Forecast of Space Technology, Outlook for Space, Management of Information

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2A3

1. TECHNOLOGY REQUIREMENT (TITLE): Software Management PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Reduce the cost of software generation (per unit produced per activity) by a factor of 10 by 1985.

4. CURRENT STATE OF ART: NASA spends probably more than two hundred million dollars yearly on software production; there is however no agency-wide effort to improve the efficiency of this process. HAS BEEN CARRIED TO LEVEL 1

5. DESCRIPTION OF TECHNOLOGY

Software management as discussed here includes all activities necessary for the organization, planning, scheduling, estimating of costs, and controlling of software production efforts. Software production is here considered to include the processes of design, coding, testing and verification, modification and maintenance, and documentation.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Despite the fact that software production accounts for a major annual expenditure by NASA, there appears to be no central office within the agency charged with the responsibility for accounting for these expenditures and promoting efforts throughout NASA to reduce them. Because of the diversity of the scope, size, and application of most software produced by the agency, its production is treated as a general expense that is to be charged to the program or project that solicits it. As a result, it is difficult to retrieve information about the distribution of costs among the various stages of software production (See 5 above). Without such knowledge, the overall efficiency of steps to reduce software cost cannot be assessed. For example, in some studies it has been found that the cost of maintenance ("ownership") may exceed the cost of generation and delivery by a factor of 10, indicating that efforts to reduce such expenditures would yield large dividends.

(Continued on Page 1a)

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2A3

1. TECHNOLOGY REQUIREMENT (TITLE): Software Management PAGE 1a OF 4

6. Rationale and Analysis (Continued from Page 1)

In addition to obtaining information about software costs, other efforts are needed to secure their reduction. Standardization of software tools as management approaches may be desirable for certain classes of software production efforts (not all) and should be promoted. Efforts to reduce duplication of effort and to increase the sharing of software and hardware facilities and expertise should be encouraged and supported. Information about advances made by one part of the agency should be widely disseminated. Research and development likely to lead to reduced software costs should be identified and its support solicited.

Such steps as are described here are essential in moving toward lower software costs. Without them, advances made through other efforts -- for example, through research in information science -- are not likely to be efficacious. Understanding what is being done is a necessary prelude to making significant improvements.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2A3

1. TECHNOLOGY REQUIREMENT(TITLE): Software Management PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

The following approaches should be examined:

a) Establishing an informative and useful management information system for the agency-wide distribution of software-related costs and efforts; b) Modeling the software production process to establish useful work-breakdown structures and cost estimation ratios; c) Standardizing selected hardware and software facilities; d) Setting requirements relating to software commandability, transportability, and documentation; e) Promoting the sharing of software and hardware facilities and expertise among the centers; f) Establishing guidelines covering configuration control, quality assurance, reliability, and maintenance; g) Identifying research and development efforts with high potential benefits for software production; h) Studying successful management techniques tested elsewhere.

8. TECHNICAL PROBLEMS:

Making the management adjustments necessary to bring about such changes in approach as are recommended here.

9. POTENTIAL ALTERNATIVES:

Watching total software expenditures rise by a factor of 10 or more over the next ten years.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Coordination of data management efforts within OA.

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

NASA network for computer facility and software sharing
Software Generation and Human-Machine Interaction
Functional Algorithm Development
Coordination of NASA Research and Development in Computer and Information Science

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2A3

1. TECHNOLOGY REQUIREMENT (TITLE): Software Management PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Study Management approaches for swc.		—	—																
2. Establish management information system(MIS)			—																
3. Implement MIS				—	—														
4. Organizational changes complete																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																	TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

Outlook for Space

Boehm, Barry W., "Software and its Impact: A Quantitative Assessment," Datamation 1q, 48-59, (May 1973).

Kosy, Dan W., "Air Force Command and Control Information Processing in the 1980's: Trends in Software Technology," Rand Report No. R-1012-PR (June 1974).

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2A4

1. TECHNOLOGY REQUIREMENT (TITLE): Automation Of Ground Support Functions PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Reduce the cost of mission-related earth-based operations 50% as a contribution toward lowering the life-cycle costs of missions 50% by 1985.

4. CURRENT STATE OF ART: The organization of mission operations and the tasks vary from mission to mission. Computers are used extensively, but an appreciable fraction of operations tasks is still done by human effort. HAS BEEN CARRIED TO LEVEL 1

5. DESCRIPTION OF TECHNOLOGY

The ground operations covered include, but are not limited to, mission planning, sequence design and command generation, training of operations personnel, flight equipment checkout, simulation, and status monitoring.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Presently, many ground-support tasks make inefficient use of human beings. As missions grow longer in duration and more complex in their objectives, and as the cost of human labor goes up, the increasing costs of ground support make it desirable to examine whether or not some of the tasks presently performed by people could be automated by making use of already existing computer software facilities and techniques. Alternatively, such methods might be used to extend the responsibilities of those humans who are involved in mission operations, or to increase the value of their efforts. It might also be possible in the course of this effort to identify functions that could be performed on the spacecraft or satellite, relieving or reducing ground responsibilities while delivering an overall cost benefit. Computers are presently used extensively in all aspects of a mission. The intent of this requirement is to take advantage of the increasing power of computer systems and bring more activities within their scope.

TO BE CARRIED TO LEVEL 2

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. 2A4

1. TECHNOLOGY REQUIREMENT(TITLE): Automation Of Ground Support Functions

7. TECHNOLOGY OPTIONS:

1) Rely on human effort entirely

2) Automate

3) Automate partially, using computer resources to enhance and extend human effort

4) Transfer more responsibility for the present ground support function to the flight system

8. TECHNICAL PROBLEMS:

1) Determining those functions for which automation is feasible

2) Achieving an efficient and inexpensive software implementation that has application beyond one mission

9. POTENTIAL ALTERNATIVES:

1) Continue the present approaches and accept the increasing costs

2) Decrease mission operations staffing and accept increased risk

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Although automation of mission control functions is often discussed informally as an objective worth studying, no systematic efforts to determine its feasibility are known.

EXPECTED UNPERTURBED LEVEL 1

11. RELATED TECHNOLOGY REQUIREMENTS:

Software cost reduction

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2A4

1. TECHNOLOGY REQUIREMENT (TITLE): Automation Of Ground Support Functions — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Study of Ground Functions		→																	
2. Feasibility assessment planning		→	→																
3. Program Implementation			→	→	→														
4. Demonstration on a Shuttle Payload								∇											
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																		TOTAL
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2A5

1. TECHNOLOGY REQUIREMENT (TITLE): Networking For NASA Computer Facility And Software Sharing PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Contribute to 10:1 reduction of software costs by 1985 by decreasing software duplication and promoting resource sharing.

4. CURRENT STATE OF ART: A network developed by ARPA is operational and undergoing use and evaluation by a large community. Other networks (for example, an NSF net) are under development or are contemplated.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

In a computer network, selected time-shared computer systems at widely separated locations ("hosts") are linked together through standard interface processors and leased high-rate telephone lines. A set of communication "protocols" established and controlled by the network governs the formatting and transfer of information from one site to another. Through terminals connected to local interface units or to message relay centers on the net, users are able to access files and programs maintained at the host sites and to develop their own files and programs on the host computer.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

In an agency as large as NASA, with its many separate offices, centers, contractors, missions, and responsibilities, it is inevitable that there will be a disparity in the computing resources--hardware and software--provided. This diversity has its benefits, but it becomes a disadvantage and an obstacle to efficient performance when several centers must combine efforts to reach a common goal or to support a common mission. To transfer software developed at one site for use at another may require translating it from one language to another, or at least adapting it to the conventions of the local operating system, processes that are usually expensive and time-consuming. The necessity for such conversion would be reduced if the centers could share designated software and computing facilities. For programs with broad NASA impact and involvement--for example, those involving the STS, the benefits would be large. Users could access simuations to determine how their data were to be accessed and delivered to them; centers with payload responsibilities could ascertain payload compatibility with shuttle operations over the net.

In time, the use of such a network should reduce the total agency software cost and facilitate the sharing of general purpose software resources. Such sharing could also reduce the computer overload at flight centers during critical mission operations by enabling the jobs of general users to be transferred to compatible machines at other installations.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2A5

1. TECHNOLOGY REQUIREMENT(TITLE): Networking For NASA Computer Facility And Software Sharing PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

1) Establish a NASA network

2) Gain user priveleges on an existing Government network

3) Lease a commercial network

4) Standardize computing facilities to facilitate software transfer

8. TECHNICAL PROBLEMS:

1) Adapting existing network technology to NASA requirements and constraints

2) Establishing a management structure that preserves center capabilities while enabling adequate and timely service to be provided to other users

3) Establishing an equitable cost allocation amongst the users

9. POTENTIAL ALTERNATIVES:

1) Continue the present separation of responsibilities and resources

2) Provide for partial sharing of resources for selected programs

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Not known

EXPECTED UNPERTURBED LEVEL NA

11. RELATED TECHNOLOGY REQUIREMENTS:

Better coordination of center data management activities

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2A5

1. TECHNOLOGY REQUIREMENT (TITLE): Networking For NASA Computer Facility And Software Sharing

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Select networking approach			▽																
2. Establish center roles and management structure				▽															
3. Procure interface hardware					▽														
4. Use network on trial basis																			
5. Place network in full operation						▽													
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2B2

1. TECHNOLOGY REQUIREMENT (TITLE): Standard Electronic Modules For Space Vehicle Payloads And Ground Support Equipment — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Significant reduction of electronic equipment development, acquisition, modification, and maintenance costs through the disciplines of standard modular construction. At least 3-to-1 life-cycle cost reduction is expected.

4. CURRENT STATE OF ART: Electronic equipment is currently fabricated from parts without discipline of form, fit, and function and is therefore extremely expensive to develop, acquire, and own. HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

The U. S. Navy Standard Hardware Program for submarines and surface ships, the U. S. Air Force program on Standard Electronic Modules and Standard Avionic Modules for ground and airborne applications, industrial (Bell System, IBM) and consumer (TV) electronics activities are examples of related progress and endorsement. These programs are showing marked potential for major cost reduction. In order to garner these benefits for NASA, one must start with system partitioning and commonality analysis to determine the proper size and complexity of functions. Modules are then fabricated and qualified, and finally equipments are fabricated for demonstration. A management control and monitoring function must be added for operational implementation in order to gain the potential benefits. The technology problem is relatively simple and inexpensive to solve; the management problems are very demanding.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) The electronics for a future vehicle such as a Shuttle follow-on, the payloads for all Shuttle flights, and the ground support of the flights can all benefit from this technology advance. Proper design has resulted in 15 minute mean-time-to-repair with semi-skilled personnel (Navy); 2-to-1 reduction in development cost and operation transition (Navy and Air Force); 3-to-1 cost reduction in maintenance (Navy sonar). More digitalization, use of microprocessors, module development and improvement, and mass production should further improve these ratios.
b) All vehicles, payloads, and ground support should benefit from this development.
c) Development time for equipment is shortened, reliability (repairability) is significantly enhanced, and parts control problems are eased (by perhaps 10:1).
d) Level 4 must be done by NASA for planning, Level 5 by NASA to prove potential, Level 6 by the Air Force, Level 7 by NASA for vehicle and payload, Level 8 by NASA as demonstration and proof validation.

TO BE CARRIED TO LEVEL 8

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2B2

1. TECHNOLOGY REQUIREMENT(TITLE): Standard Electronic Modules For Space Vehicle Payloads And Ground Support Equipment PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

A spectrum of difficulty exists from ground equipment to mission support to payloads to space vehicles. The payloads and vehicles will require space qualification. The other areas can utilize technology and standards generated by DOD. However, considerable study and analysis is required to determine the proper utilization of the standards. Another spectrum of technology is involved in defining the complexity of modules and the development level of device technology. (See the Technology Requirement "Modular Architecture.") Correctly partitioned, modules can survive several eras of device technology changes and still retain a single functional description.

8. TECHNICAL PROBLEMS:

a) User acceptance. Many engineers and companies like to express their egos and gain profits through reinvention and minor changes. They tend to resist any standardization efforts. Therefore it will be important to hold only to form, fit, and function standards, not to technology.

b) Selection of the proper size, complexity, and pinout of the modules.

c) Maintenance. Generating a maintenance concept and standard BITE or fault location technique.

9. POTENTIAL ALTERNATIVES:

To make significant reductions of life-cycle costs for electronic systems, NASA appears to have few alternatives open other than minor variations on the module concept.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Navy and Air Force programs plan to make this technology available in advanced form for use in high performance aircraft. SAMSO is developing GPS receivers at Texas Instruments using similar standard modules. NASA has no known programs to utilize this developing technology or perturb it to meet its needs.

EXPECTED UNPERTURBED LEVEL 6

11. RELATED TECHNOLOGY REQUIREMENTS:

For optimum utilization of the potential of SEM's it is necessary that considerable attention be paid to: 1) modular system architecture; 2) modular software; 3) thermal design; 4) maintenance concepts; 5) system partitioning for fault isolation and built-in test.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2B2

1. TECHNOLOGY REQUIREMENT (TITLE): Standard Electronic Modules For Space Vehicle Payloads And Ground Support Equipment

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis and System Partitioning																			
2. Module Definition and Fabrication																			
3. Ground Equipment Demonstration																			
4. Payload Demonstration																			
5. Management Procedures Development																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES						2	25	25	25	25	25	25	25	25	25	25	25	277

14. REFERENCES:

a) U. S. Dept. of the Navy - Standard Hardware Program
Naval Electronics and Naval Avionics Facility, Indianapolis

b) U. S. Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio; McLawrance Porter

c) Hughes Aircraft Co., Culver City, California.

d) Research Triangle Institute, Research Triangle, North Carolina

e) Hydro-Space Challenges (Consultants), Washington, D.C.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2B3

1. TECHNOLOGY REQUIREMENT (TITLE): Fault Tolerant Electronic Systems — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: Reliable operation of vehicle and payload electronic systems in spite of component failures or software and transmission errors.

4. CURRENT STATE OF ART: Systems are built of very reliable LSI components with redundancy of equipment in vulnerable areas.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

Considerable research is currently underway in the area of fault tolerant computers. This effort is documented in a recent issue of the Proceedings of the IEEE. The next required steps are to reduce this theory to practice, for NASA experiments, and then extend it to whole digital information systems and finally to whole vehicle electronic systems. Flight controls, engine controls, and electrical controls as well as avionics will profit from this effort. Biological systems offer analogous behavior that one would like to imitate, as a possible pattern of future research. The existance of very inexpensive microprocessors and memory elements suggests that a study made of what a fault tolerant system would be like, assuming infinite data processing capability available at zero size and cost, would be extremely valuable. It appears that operational systems designed for fault tolerance will be possible by 1990 if adequate support is generated.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) All shuttle payloads and advanced vehicles need this technology. Here we want 100% performance for reasonably short periods. Planetary missions must operate over extremely long periods without catastrophic failures. These are probably different designs dependent on weight-cost tradeoffs.

b) Since reliable electronics is part of all payloads and experiments, fault tolerance applies to all.

c) Done correctly, it is believed that electronics systems can be built to possess nearly infinite life, based on components at the known reliability of 2×10^9 hours MTBF, if maintenance is allowed; i.e., manned vehicles, or ground support equipment. Theoretical studies would need to be performed to extend the concept to unmanned vehicles without maintenance possibilities. (Distributed redundancy?)

d) Since much of the required work is theoretical in nature and leads to system organization rather than manufacturing techniques, it should be quickly reflected in operational systems. The future of electronics systems is directly tied to this area of endeavor, and it is unknown without considerable research.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2B3

1. TECHNOLOGY REQUIREMENT(TITLE): Fault Tolerant Electronic Systems PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

a) Continue to expend inordinate amounts of money on super-reliable components and still not have reliable systems.

b) Go to redundancy (2,3,4, etc.) at great cost and throw-weight increase and still not have reliable systems.

c) Create a fault tolerant system concept and operate for long periods on a gracefully degrading basis.

8. TECHNICAL PROBLEMS:

a) Develop a mathematical theory of such systems.

b) Simulate, model, and explore such system concepts.

c) Reduce to practice.

9. POTENTIAL ALTERNATIVES:

As requirements for automation and autonomous operation of more complex missions continue to increase, there is no known alternative to this area of research.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The Air Force Avionics Laboratory is planning to support effort in this area. JPL has identified an RTOP 506-20-11 which is related or primary to this effort.

EXPECTED UNPERTURBED LEVEL 2

11. RELATED TECHNOLOGY REQUIREMENTS:

Artificial Intelligence, digital systems, computers, software, coding theory.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2B3

1. TECHNOLOGY REQUIREMENT (TITLE): Fault Tolerant Electronic Systems

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Theory																			
2. Computers																			
3. Digital Systems																			
4. Systems																			
5. Demonstration																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																	TOTAL
NUMBER OF LAUNCHES																	

14. REFERENCES:

a) IEEE Proceedings - Fault Tolerant Computing

b) USAF Project 4159 - Fault Tolerance (work element)

c) USAF Office of Scientific Research, Major R. Bush

d) JPL Proposal for Grand Tour

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2C1

1. TECHNOLOGY REQUIREMENT (TITLE): System Engineering Techniques Using Modeling And Simulation — PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Systems, Software

3. OBJECTIVE/ADVANCEMENT REQUIRED: Systems engineering on end-to-end system through the use of modeling and simulation to identify items requiring technology development.

4. CURRENT STATE OF ART: End-to-end modeling is currently underway at MSFC with emphasis on system utility optimization.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Through the use of modeling and simulation of end-to-end systems, system engineering trades are to be performed on selected system configurations to allow not only the determination of near-optimum system configurations (and preferred modes of use) but to identify technology "bottlenecks" which require additional improvement to be cost effective. Cost, throughput, operations, missions, device, and problem models are to be used to allow all elements of the end-to-end system to be quantatively considered. The level of modeling (i.e., global, etc.) shall be only to that level necessary to give the desired fidelity at the least cost.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

A relatively inexpensive, flexible (easily and rapidly reconfigurable) way to perform end-to-end trades (and allow one to optimize information/data ratios) on selected system configurations is needed. With improvements in such system engineering techniques, several potential advantages are apparent. For example, projected data rates may well be lowered below those presently thought by some to be needed. Should such prove to be the case, perhaps certain very high data rate items would not have to be developed (thereby affecting savings). Through such end-to-end considerations the technology development could be concentrated on those elements most urgently (and pragmatically) needed.

TO BE CARRIED TO LEVEL 4

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2C1

1. TECHNOLOGY REQUIREMENT(TITLE): System Engineering Techniques Using Modeling And Simulation

7. TECHNOLOGY OPTIONS:

o Selected subsystem or element modeling and simulation

o System analyses without simulation or modeling

8. TECHNICAL PROBLEMS:

o Proof of model and simulation fidelity

o Tendency to "overmodel" with software

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL __

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2C1

1. TECHNOLOGY REQUIREMENT (TITLE): System Engineering Techniques Using Modeling And Simulation PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Model Dev.																			
2. First Simulation			∇																
3. Proof of Models		∇	∇	∇	∇	–	–	–	–	–	∇								
4. Subsequent, Higher Level Simulations		TBD																	
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GST-1

1. TECHNOLOGY REQUIREMENT (TITLE): Transfer Of Space Power By Microwaves PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: ____________

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop the capability to transfer commercially useful amounts of power (5GW) from synchronous orbit to earth by means of microwave transmission.

4. CURRENT STATE OF ART: Basic mechanisms (tubes, antennae, power transmission) have been demonstrated on a very small, select scale.

HAS BEEN CARRIED TO LEVEL 4

5. DESCRIPTION OF TECHNOLOGY

Studies show that high power/efficiency tubes (5KW @ 90%), high gain/efficiency antennas (92db @ 90%), and extremely accurate pointing (.0050) will be required to transfer commercially useful amounts of power from space to earth. Further, these components must be integrated into a system that will function reliably for several decades and must be extremely reliable. None of these components exist today, nor have methods of integration been demonstrated. A development program, culminating in an orbital demonstration, is proposed.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

In May 1975, the Jet Propulsion Laboratory radiated 35Kw of microwave power over a one mile range, using an 85' dish as the radiator and a 45,000 square foot rectenna as the receptor. Useful power levels and efficiencies were obtained, demonstrating the concept of microwave power transmission. In order to be economically viable as a power utility source, a power transmission system will require the following technological advances:

a) High Power Efficiency Tube--The prime space power source may be solar cells, solar concentrator/Brayton Cycle, or some similar technology and is expected to constitute the bulk of power station mass. Inefficiencies downstream of the power source will be reflected in greater mass and cost. Therefore, the DC/RF/DC conversion efficiency, which is the product of series efficiencie must be held as high as possible, preferably above 60%. To achieve this level, the tubes must operate above 90% efficiency. The Amplitron has demonstrated 85%, and studies indicate 90% is achievable in a tube operating at 5Kw. To be economically viable, such a tube must also have long life, lightweight, and be inexpensive. By eliminating the tube envelope, and using a new magnet material, weight per 5Kw tube can be reduced to about four pounds. A cold cathode will eliminate the predominant failure mechanism.

(Cont.)

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GST-1

1. TECHNOLOGY REQUIREMENT(TITLE): Transfer Of Space Power By Microwaves PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

Development of an economically viable microwave power transmission system appears to be an extremely difficult task. The discussion of specific approaches in the previous paragraph treats what appears to be the best candidate on the basis of studies so far conducted. However, selection of tube type, power levels, antenna type, gain, and control may all change as result of an extensive development program.

8. TECHNICAL PROBLEMS:

a) Tubes without envelopes cannot be used on earth, and the extreme vacuum of space cannot be simulated. Concerns such as cathode contamination and tube start-up cannot be fully allayed until orbital flight test.

b) Antenna gains such as required have not been approached.

9. POTENTIAL ALTERNATIVES:

Lasers have been suggested as an alternative medium of transmission. However, tremendous increases in power level, efficiency, and reliability would be required.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Comparatively low levels of development are proceeding in tubes and phase control.

EXPECTED UNPERTURBED LEVEL 4

11. RELATED TECHNOLOGY REQUIREMENTS:

a) Space processing may be required, at least in final stages such as outgassing, for tubes.

b) Space assembly will be required for integration of components larger than Shuttle delivery capability.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GST-1

1. TECHNOLOGY REQUIREMENT (TITLE): Transfer Of Space Power By Microwaves PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Component Development			—	—	—	—													
2. System Integration					—	—	—												
3. System Ground Test						—	—	—											
4. Development Flight									—	—	—								
5. Go-ahead Decision												X							
APPLICATION																			
1. Design (Ph. C)												—	—						
2. Devl/Fab (Ph. D)														—	—	—	—	—	—
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GST-1

1. TECHNOLOGY REQUIREMENT (TITLE): Transfer Of Space Power By Microwaves PAGE 4 OF 4

(Cont.) 6. RATIONALE AND ANALYSIS:

However, such tubes are thought to be susceptible to contamination in space. Hence, while the tube development appears feasible, demonstration (and perhaps final manufacturing processing) in the space environment will be essential.

b) Antenna--The antenna efficiency should also be about 90%. Common efficiencies are 55%. Antenna gain requirements are estimated above 90 db, which is much greater than anything now available. These parameters appear to rule out a dish antenna and indicate a slotted waveguide planar array with an aperture diameter of 1Km. Such an antenna cannot be launched directly, but must be segmented into subarrays for Shuttle launch, or be fabricated in space. Key development concerns are 1) Subarray design for efficiency 2) Tube/array integration and 3) Subarray tilt control within 0.5° to maintain planar configuration. This last attribute must be demonstrated in space, under expected dynamic loads.

c) Phase Control--The electrical phase across the antenna must be controlled to within 10° RMS. This is the equivalent, at S-Band, of a mechanical absolute flatness tolerance of 5mm. Such a mechanical tolerance is not feasible. It will be necessary to develop electrical phase control that will automatically compensate for mechanical distortions. The most promising approach is active retrodirectivity, in which the phase of an upcoming pilot signal is electronically conjugated and used as the reference for phase control in each element. This approach requires considerable electronics, none of which have been developed. Those to be developed must be low in both weight and cost, but extremely reliable.

d) Rectenna--The rectenna is a combination antenna and rectifier that converts microwave power directly to DC power. It has been demonstrated in hardware, but it requires advances in efficiency and in low-cost fabrication.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GST-2

1. TECHNOLOGY REQUIREMENT (TITLE): Radiation Tolerant Electronic Components And Subsystems PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Systems

3. OBJECTIVE/ADVANCEMENT REQUIRED: To determine the radiation tolerance of the various semiconductor technologies as they are applied in spacecraft electronic subsystems.

4. CURRENT STATE OF ART: Certain technologies have demonstrated varying degrees of tolerance in laboratory tests using high dosages over short periods of time.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

It is necessary that a semiconductor technology for LSI and discrete components be selected for use in subsystems such that their continued satisfactory performance be assured when exposed to long periods of high energy gamma and particle radiation. Proper selection of other materials for structural and shielding purposes is also required to minimize secondary emissions.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

There currently are a number of semiconductor technologies in existence or under development and numerous variations within each type. Each has certain characteristics which make it more or less suited to use in spacecraft subsystems. Some of these such as speed, power, voltage level, density, difficulty in manufacture, cost and reliability are well known or can be determined through ground investigation and testing. One characteristic, though, has not received sufficient investigation and testing, namely the semiconductor's tolerance to high energy, long duration space radiation. Such conditions are found in the earth's Van Allen belts, at geosychronous altitudes, during interplanetary transit, and in the Van Allen belts of other planets.

It is possible to perform limited investigations of these phenomena in the laboratory using radiation sources and large particle accelerators. High energy particles can be obtained for short periods of time and the results extrapolated for projected mission times up to 5 years, but actual testing of long-term effects is not possible due to technical difficulties and high cost.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT NO. GST-2

1. TECHNOLOGY REQUIREMENT(TITLE): Radiation Tolerant Electronic Components And Subsystems PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

The technology options open for consideration include bipolar, MOS (including PMOS, NMOS, CMOS), and I^2L. Variations in substrate material, doping materials, and in processing, assembling, and packaging techniques result in many combinations of the above.

8. TECHNICAL PROBLEMS:

The development of test support equipment either not susceptible to the radiation environment or whose effect can be measured and removed. Possible alternate could be the use of a passive spacecraft for recovery after the 3 year period.

9. POTENTIAL ALTERNATIVES:

Establishment of a laboratory facility for the continuous generation of high energy radiation particles over an extended period of time, approaching years.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Further development of the newer CMOS and I^2L technologies into useful components for spacecraft application.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. GST-2

1. TECHNOLOGY REQUIREMENT (TITLE): Radiation Tolerant Electronic Components And Subsystems

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Dev. Candidate Components																			
2. Dev. Test Support Hardware																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

V. FLIGHT EXPERIMENTS

A. Rationale

Associated with the technology requirements identified in Section IV, the Data Processing and Transfer Group analyzed the need for testing and validation of technological advances. It was determined that only a portion could be adequately brought to a state of flight readiness and acceptance through ground test.

For some technology areas, adequate simulation of the total effects of the space environment would actually be more costly than a space test aboard a shuttle flight. Anything less would result in an unacceptable risk to major users of the technology. Furthermore, in certain cases only a space test can provide the required data, for instance, operations in zero-g. Finally, detailed comparisons of existing flight equipment/technology and proposed new equipment/technology designed specifically for space application can be made more meaningful in the environment in which both operate.

B. EXPERIMENTS

A total of eleven (11) flight experiments were selected for initial consideration in the area of Data Processing and Transfer. They are listed in Table V-1. Each flight experiment is subsequently discussed in narrative form and then documented on form FT (TDR) 7/75 "Future Payload Technology Testing and Development Requirement".

DATA PROCESSING & TRANSFER

FLIGHT EXPERIMENTS

	MAJOR THRUST #1 - 1000:1 INFORMATION CAPACITY INCREASE	
1.	End-to-End Integrated Data System	M
2.	High Capacity Ku Band Communication Terminal	M
3.	Laser Data Relay Link	M
4.	Communication Technology Experiments	O
5.	Preprocessor For Multifrequency Synthetic Aperture	M
6.	Onboard Manned Interactive Multisensor Image Processor	M
7.	Advanced Teleoperator Vision System	M
	MAJOR THRUST #2 - 10:1 LIFE CYCLE COST REDUCTION	
8.	Modular Architecture for Data Processing & Transfer System	M
9.	Automation of Group Support Functions	M
10.	Radiation Tolerant Electronic Components & Subsystems	M
	SUPPORTING TECHNOLOGY	
11.	Transfer of Space Power by Microwaves	M

(M-Mission Driven)
(O-Opportunity Driven)

TABLE V-1

B.(1) End-to-End Integrated Data System Description

After both ground tests and space tests of the basic elements of new technology for data processing and transfer systems, it is proposed that a major portion of a spacelab-type mission be dedicated to flying a data system laboratory. Associated with the laboratory would be two secondary active satellites, one in the same orbit as the laboratory with a TBD° phase difference, the other in a geosynchronous orbit. A ground station would also be an integral part of the test.

The basic purpose of such a space test would be to test and validate optimized end-to-end system technology for various space applications, i.e., earth sensing, communications, deep space, etc. Users and potential users would get a first-hand demonstration of total system response from sensors to final reduced data output. Manned interaction would be included where automated aspects of the system for a given application had not reached final maturity. The laboratory, therefore, would not be for scientific purposes, but would basically serve as a technology proving ground.

The laboratory would be equipped with <u>total</u> data systems from sensors through transmitters/antennas. In some cases, parallel systems or elements would be available for comparative purposes. Examples:

antennas - range of types for various space applications

transmitters - solid state, high power tube, etc.

receivers - low tem/noise, uncooled, etc.

lasers

both centralized and distributed processors

modular, fault tolerant computers

sensors - range of types for various space applications storage devices - tape, disk, bubble, etc.

The two secondary satellites would be active, with power and stabilization. They would be equipped with state of the art terminals for the various communication links and selected commandable stimuli for sensors on the laboratory.

A ground station would be required to provide data receiving/ display capability, command uplink, and to serve as a controlled platform for testing ground-to-satellite remote data gathering capability. The ground station would be automated as much as possible to demonstrate minimized human involvement in final data outputs and mission control.

In orbit, sensors of various types would be stimulated by real and controlled inputs. Certain stimuli would be commandable on the two secondary satellites and the ground. Sensor data would be processed onboard and transmitted over the various RF communication links. Air-to-ground data would be received and evaluated by the ground station. Air-to-air data would be received and retransmitted (bent pipe) back to the laboratory for evaluation. Feature recognition techniques would be refined through man interaction.

Analysis would be made on all aspects of systems performance. Both the laboratory and ground crews would vary system parameters in controlled modes to determine performance limits. Some in-flight modification of systems would be possible to correct unforeseen deficiencies.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V. B. I.
PAGE 1

1. REF. NO. ______ PREP DATE 8/11/75 REV DATE ______ LTR ____
CATEGORY Data Processing and Transfer

2. TITLE End-to-End Integrated Data System

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Development of End-to-End Integrated data system which is automated/autonomous to maximum extent and incorporates on-board data extraction and processing including reduction and compression, with a high efficiency, high data rate RE transmission link(s). For Air-to-Ground and Air-to-Air Data transfer. Output to users should be provided in reduced form in the desired measurement units. Optimization of system design and use of modular architecture are required to permit system variations for different space applications, i.e., earth sensing, communications, deep space, etc. Inherent in system design will be the optimization of software (partitioning, management, etc.).

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS This advancement will make possible the collection, processing and transfer of larger quantities of data from a given payload/spacecraft than would otherwise be possible. This would therefore permit use of more complex sensors and more total experiments/sensors on each specific payload/spacecraft.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES Development of better on-board antenna pointing accuracy (final accuracy requirement based on tradeoffs performed during system development).

7. REFERENCE DOCUMENTS/COMMENTS ES-38, Outlook For Space, Executive Summary Dreft July 1975 Themes 01,02,03,05

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TITLE End-to-End Integrated Data System — NO. ____

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION — TEST ARTICLE: Progressive space testing of system elements and then a low earth orbit data system laboratory (manned) with two secondary active satellites (one in same orbit as laboratory with TBD° phase difference and the other in geosynchronous orbit.

TEST DESCRIPTION: ALT. (max/min) 350 / 275 km, INCL. 28.5 deg, TIME ____ hr

Perform demonstration and testing of end-to-end system(s) developed for each major mission application i.e. earth sensing, communications, deep space, etc.

BENEFIT OF SPACE TEST: In space environment with actual sensor data, vehicle stabilization/pointing dynamics, remote operation, etc.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: Ground station to provide data receiving/display command up link, serve as controlled platform for remote data gathering. Highly automated.

EXISTING: YES ☐ NO ☒

TEST CONFIDENCE ____

9. GROUND TEST OPTION — TEST ARTICLE: Necessary demonstration/testing cannot be performed adequately by ground test.

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ____

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY 81	82	83	84	85	86	SPACE TEST OPTION COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS	—	—												
2. DESIGN		—	—											
3. MFG & C/O			—	—										
4. TEST & EVAL					—	—								
TECH NEED DATE														
GRAND TOTAL								GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM — COST IMPACT — PROBABILITY

COST RISK $ ____

FT (TDR-2) 7/75

B.(2) High Capacity Ku-Band Communications Terminal

Space Shuttle is tasked with providing wide band communications support for payloads and experiments. While the data transfer requirements are not stabilized, one megabit per second on the forward link and fifty megabits per second on the return link, are generally accepted. These data rates will not satisfy all user requirements, and it is problematical whether the Shuttle will be able to implement links to handle even these data rates. Therefore, it appears that a second generation Ku-Band terminal for operation through TDRSS will be required.

A second generation Ku-Band terminal with color TV on the forward link and 200 megabits on the return link appears feasible and desirable. Such a terminal would employ an unfurlable dish antenna with integral transmit/receive electronics. The dish equivalent size should be about five feet, but it should fit in the space now allocated for the Orbiter twenty-inch dish. It would be highly desirable to have the dish and electronics structurally integrated in order to reduce gimbaled weight, while reducing losses and eliminating rotating pressurized waveguide joints.

The proposed terminal will interact strongly with the zero-G/thermal/vacuum environment of space. Gimbaled weight must be kept down and thermal properties must be controlled. It will be highly desirable to gain experience with the terminal in space without requiring the payloads to depend entirely upon its reliability. Therefore, a series of flight experiments are proposed in which the terminal is successively located on Spacelab Pallet and on the second twenty-inch dish mount. In this way the new terminal can demonstrate its flight-worthiness without significant risk to the payload mission.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V.B.2
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY ______

2. TITLE High Capacity Ku-Band Communications Terminal

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Integrated Ku-Band Antenna/Electronics, including furlable antenna, solid state Ku-Band power amplifier, and low-noise, image-enhanced receiver/down converter.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1982
PAYLOAD DEVELOPMENT LEAD TIME 1 YEARS. TECHNOLOGY NEED DATE 1980

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS Increased payload communication capacity through baseline TDRSS. Specifically, forward-link TV and 200 MBPS return link.

POTENTIAL COST BENEFITS With greater bandwidth, fewer flights will be required to accomplish the same data gathering and transfer.

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS Gimbaled mass minimization, temperature stabilization.

REQUIRED SUPPORTING TECHNOLOGIES Flexible heat pipes

7. REFERENCE DOCUMENTS/COMMENTS Users Guide, Outlook for Space, Space Shuttle Systems Description
RTOP 310-20-46 RF Technology per TDRSS User Spacecraft - OTDA/GSFC
RTOP 506-20-24 Microwave Near Earth Data Transfer and Tracking - OAST/GSFC
RTOP 909-44-07 Space Communication and Tracking - OMST/JSC

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TITLE ______ NO. ______

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Benefit of Space Test: Zero-g test of mass gimbaling and true thermal-vacuum assessment of temperature control.

TEST DESCRIPTION: ALT. (max/min) ____/____ km, INCL. ____ deg, TIME ____ hr

Test antenna to be carried on Orbiter and used to demonstrate full data transfer capability.

BENEFIT OF SPACE TEST: Verification of electromechanical and electrical interfaces in zero-G/vacuum/thermal environment

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING 0.5° STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____/____

SPECIAL GROUND FACILITIES: N/A

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: Same

TEST DESCRIPTION/REQUIREMENTS: Tracking and interface tests with prototype or flight article using antenna range.

SPECIAL GROUND FACILITIES: None

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: Steerable antenna operation is strongly affected by zero-G/vacuum/thermal environment which cannot be duplicated on earth.

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	77	78	79	80	81	82	COST ($) (SPACE TEST OPTION)							COST ($) (GROUND TEST OPTION)
1. ANALYSIS		X-	-X												
2. DESIGN			XX	----	X										
3. MFG & C/O					X---	--X									
4. TEST & EVAL							X								
TECH NEED DATE					X										
GRAND TOTAL															

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

Dish-Electronics interface thermal properties and gimbaled mass

COST RISK $ ______

FT (TDR-2) 7/75

(3) Laser Data Relay Link

Planned earth observation or planetary spacecraft employing high data rate sensors such as thematic mappers, synthetic aperture radars, multispectral sensors, or TV imaging systems will generate data at rates up to one gigabit per second. Current and planned microwave data transfer systems, such as the Ku band system to be flown on TDRSS, are limited by physical constraints to data rates on the order of 200-250 megabits per second. User spacecraft must therefore provide complex, costly onboard processing of data, or operate at reduced capabilities, to meet the limitations imposed by available data links.

Laser systems offer bit rates compatible with the requirements of future payloads and can eliminate the operational constraint of limited data transfer capability. A coherent CO_2 laser system has been built and operated in a laboratory environment at 300 megabits per second. 25 centimeter telescopes acting as receivers at both the receiving and transmitting stations can, in conjunction with currently available laser tubes, provide sufficient margin to operate this system from earth to synchronous altitudes. Tracking and data acquisition requirements have also been examined in the laboratory, and lock up rates compatible with a synchronous orbit to ground or low-earth to synchronous orbit data link have been demonstrated in simulated operations. CO_2 laser life tests have been conducted, and adequate operating life (greater than 10,000 hours) has been demonstrated. Space testing of the laser system is needed to validate system performance and examine operational procedures and constraints.

The proposed experiment would consist of two phases. The initial phase would be launch of a laser transceiver on a free-flying payload at synchronous altitude. The free flyer would be exercised with an existing ground station at GSFC to demonstrate up-down high rate data transfer, to prove tracking and acquisition requirements can be met, and to establish operational procedures. Assuming the free flyer phase successfully met its objectives, the second phase would involve installation of a laser transceiver in a shuttle payload in low earth orbit. This system would then be operated in conjunction with the free flyer to demonstrate the space-to-space capability of the laser data relay link and its suitability for use as the high rate data link in a second generation TDRS system.

(4) Communications Technology Experiments

The quality of a society is in direct proportion to the quality of the interactions among members of the society. Communications provides the principal means of accomplishing such interaction, and as societies become more far-flung, the required instantaneity and simultaneity must increasingly be provided by telecommunications or communication at a distance. Although, at least in the U.S., the mainstay of this communication network will continue to be the highly developed national telephone network (approximately a $60 billion investment) the recent advent of the communications satellite offers the hope of making the familiar long distance telephone call less expensive, while at the same time making possible entirely new options for communications, which would be prohibitively expensive, or even impossible without the satellite.

Ships at sea and mobile vehicles in remote places on the land can be put in immediate touch with those who remain at home. Aircraft operating over the oceans can be in direct touch with flight controllers and derive from satellites accurate information on their position and that of nearby aircraft. The remotest archeological team or oil exploration party will be able to stay in touch with scholarly communities, data sources and libraries, computers, etc. Mail will someday be transmitted instantaneously by satellite. Someday the continuous process of education will be able to take place at times and locations convenient to each individual learner, mediated by satellites, without regard to remoteness from centers of learning. X-rays of remotely located patients will be transmitted by satellite to great medical centers where diagnoses will be made by experts. Entertainment and educational programs will be beamed down not only to enhance the quality of life in the U.S. but to make it possible for anyone in the world to partake of the world feast of knowledge and culture.

Search and rescue packages will permit authorities to rapidly find and aid downed aircraft and lost persons in remote areas.

Data may be collected from sensors on inaccessible volcanoes, permitting prediction of eruption; from stream gages to predict floods in time to evacuate the populace; from agricultural sensors to permit control of crop pests; and from climatological and pollution monitors around the world.

Disaster warning satellites may broadcast timely warnings of tsunamis, tornadoes, severe storms, hurricanes, floods, and other disasters directly to home, office, and neighborhood warning receivers, thus permitting large scale saving of lives.

Access to the world's most sophisticated giant computers may be provided to qualified scientists throughout the world to harness the computer's power for the continuing rapid advancement of beneficial science and technology.

In the meantime, the burgeoning satellite technology will have begun to affect favorably the existing public switched message network. Already it has made possible manyfold increases in overseas telephony, and has begun to make an impact on long distance telephone rates.

In the future it may increase our enjoyment and awareness by making possible a great increase in the frequency of live television broadcasts of national and international events - a circumstance that was impossible or prohibitively expensive only a few years ago. It may make possible a much greater richness of entertainment and education through pooled TV programs as in program sharing by CATV owners.

Carried to its extreme, by the year 2000 such concepts as personal communications between individuals anywhere in the world carrying miniaturized communications gear may become feasible. Simultaneous rapid advances in terrestrial communications technology, such as light pipes and coaxial cables will have released orbital and spectrum allocations for use in a wide variety of specialized communications missions tailored to use by individuals for their education, enjoyment, and social contact.

All the above things are likely to come to pass somewhere. They can come to pass in the United States if we have the will to make them happen. The corresponding electronics technology has a great potential for improving the economy of the United States as a technology exporter and creating a more favorable balance of payments in particular.

Communications technology is characterized by typical growth rates of 15-20% per year and more, and by doubling periods of 3 to 5 years. In such a rapidly growing field the competition can be lost by even momentarily faltering or hesitating in pursuing the initiative. The U.S. gained an early lead in telecommunications satellites in the early 60's and must now work hard not only to maintain it but partially to retrieve it.

The shuttle represents a way to regain the lead. The proposed shuttle communications experiments will provide the stimulus to a continuing series of communications technology developments that may enable the U.S. to retrieve and maintain the competitive edge.

The experiments are based on four groups of technologies direct broadcast/narrowcast, satellite data collection, spectrum monitoring and telephony/trunking.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V. B. 3
PAGE 1

1. REF. NO. ______ PREP DATE 8/12/75 REV DATE ______ LTR ______
CATEGORY ______

2. TITLE Lasers Data Relay Link

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
5	5	7

Provide a laser communication system capable of transferring data at rates of 300 megabits per second or higher. The system must be competitive in cost and performance with microwave or millimeter wave alternatives, must demonstrate growth capabilities to one gigabit per second for future applications, and must be able to operate in a low-earth-orbit to synchronous orbit data relay link mode. Engineering prototype systems have been tested in a laboratory environment. Space flight testing is necessary to validate performance and eliminate operational unknowns.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1985
PAYLOAD DEVELOPMENT LEAD TIME 3-4 YEARS. TECHNOLOGY NEED DATE 1981

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS Increased data transfer rates compatible with EOS and other imaging type payloads including planetary images.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Modulation techniques currently limit the attainable data rates for coherent systems. Detector sensitivity and laser efficiency need improvement to increase the link margins for noncoherent systems.

REQUIRED SUPPORTING TECHNOLOGIES Long life, space qualified lasers; advanced detector technology; laser pumping techniques; modulator/demodulation concepts and components.

7. REFERENCE DOCUMENTS/COMMENTS A NASA/DOD Joint Spacecraft Laser Data Relay Link (LRDL), Volume I and II, GSFC, May 1974

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TITLE Laser Data Relay Link

NO. ______

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Laser data relay link capable of 300 megabits per second operation from synchronous altitude

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Demonstrate laser communication system as a high rate data transfer link

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: Ground-based receiver/transmitter to exercise system

EXISTING: YES [x] NO [ ]

TEST CONFIDENCE 0.9

9. GROUND TEST OPTION TEST ARTICLE: Test laser transceiver in simulated high data rate application.

TEST DESCRIPTION/REQUIREMENTS: Transceiver operating at maximum data rate with retroflector to simulate data link.

SPECIAL GROUND FACILITIES: Test range with appropriate telescopes, instrumentation and supporting equipment to validate system operation.

EXISTING: YES [x] NO [ ]

GROUND TEST LIMITATIONS: Does not test acquisition and tracking problem nor demonstrate operation in a realistic environment where effects on propagation can be assessed.

TEST CONFIDENCE 0.3

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

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FUTURE PAYLOAD TECHNOLOGY **NO.** V.B.4
TESTING AND DEVELOPMENT REQUIREMENT **PAGE** 1 of 2

1. REF. NO. ______ **PREP DATE** ______ **REV DATE** ______ **LTR** ______
CATEGORY ______

2. TITLE Communications Technology Experiments

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Series of direct communication technology advancements:
High power tubes; large microwave arrays; higher frequency components; local program insertion techniques; on-board switching etc.

4. SCHEDULE REQUIREMENTS **FIRST PAYLOAD FLIGHT DATE** 1980-1982
PAYLOAD DEVELOPMENT LEAD TIME 2-3 **YEARS. TECHNOLOGY NEED DATE** 1979

5. BENEFIT OF ADVANCEMENT **NUMBER OF PAYLOADS** 5 t
TECHNICAL BENEFITS More efficient utilization of frequency spectrum
Better satisfaction of user needs for communication system
More advanced technology in above areas

POTENTIAL COST BENEFITS Much reduced cost of telecommunications, particularly unswitched applications

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS Technologies must be demonstrated to convince private enterprise to risk using them in operational systems

REQUIRED SUPPORTING TECHNOLOGIES Power, navigation, processing and data handling, attitude control, structures

7. REFERENCE DOCUMENTS/COMMENTS See attached sheet

FT (TDR-1) 7/75

TITLE ______ NO. ______

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Series of 5 + more or less tightly integrated compatible communication technology experiments as synchronous free-flyers

TEST DESCRIPTION: ALT. (max/min) Synch. / Orbit km, INCL. ______ deg, TIME 24 hr

BENEFIT OF SPACE TEST: Technology verification in space environment + user familiarization/demonstration

EQUIPMENT: WEIGHT 2000-10,000 kg, SIZE ____ X ____ X ____ m, POWER 2-20 kW

POINTING $\pm$ .1° or better STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: Series of user furnished

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION TEST ARTICLE: DNA

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	CY	Space 77	78	79	80	81	82	Space COST ($)	Ground						Ground COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
GRAND TOTAL								100M							

11. VALUE OF SPACE TEST $ 100M (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

DNA

COST RISK $ ______

FT (TDR-2) 7/75

References

Outlook for Space — Executive Summary July 1975
Technology Forecast July 15, 1975
Working Papers and Interim Review May 28, 1975

National Research Council Snowmass Study November 6, 1974

(5) Preprocessor for Synthetic Aperature Radar

Multifrequency wideband synthetic aperature radars have been identified as a technology requirement for future earth observation experiments. This type of sensor produces very wide bandwidth data. Estimates of the required bandwidth run as high as 460 megahertz. The present state of the art in data communications and storage is incapable of supporting more than a few minutes of sensor operations per day.

Onboard processing for this data is a necessary requirement for useful spacecraft applications of the synthetic aperature radar. The only presently viable approach to onboard processing of this data uses CCD technology to perform range and azimuth correlation and compression correlation of the multiple-look return data. The composite superimposed image thus produced is then subjected to conventional image compression also using CCD's. A potential data reduction in excess of 100 to 1 can be achieved by such a processor. Therefore the resulting data rates in the range of .5 to 5 mHz make spacecraft application of the synthetic aperature radar feasible.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V.B.5
PAGE 1

1. REF. NO. ______ PREP DATE 8/8/75 REV DATE ______ LTR ______
CATEGORY Systems

2. TITLE Preprocessor For Multifrequency Wideband Synthetic Aperture Radar

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Development of a high speed parallel processing system which can be flown in space as part of a multifrequency, wideband synthetic aperture radar (SAR) experiment. This preprocessor must be capable of 1) accepting data directly from the SAR, 2) performing the required preprocessing transforms in real time, and 3) formating the transformed data into a format compatible with on-board data storage and/or down link data communications. Present SAR's have no pre-processing. Technology developments have begun to be directed toward this goal.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 2

TECHNICAL BENEFITS This advancement will make it possible to operate multi-frequency wideband synthetic aperture radars from orbital altitudes without saturation of the down link capabilities of the spacecraft.

POTENTIAL COST BENEFITS Tremendous savings in ground based data processing, reduced cost of on-board data transmission components.

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Extremely high data rate processing required. Resolution requirements of the preprocessor.

REQUIRED SUPPORTING TECHNOLOGIES Development of high speed parallel processing elements such as programmable CCD's.

7. REFERENCE DOCUMENTS/COMMENTS FT-WP-001 (General Dynamics) p. 69
AAFE On-board Radar Image Processor OA/JPL

FT ITDR 11/7/75

TITLE Preprocessor For Multifrequency Wideband Synthetic Aperature Radar

NO.

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: SAR preprocessor--possibly having limited capability such as single frequency, or lower resolution requirements.

TEST DESCRIPTION: ALT. (max/min) 250 / 170 km, INCL. 57 deg, TIME 15 hr

Operate preprocessor with actual data from SAR over ground truth sites in the U. S.

BENEFIT OF SPACE TEST: It is essential to test the preprocessors with actual data.

EQUIPMENT: WEIGHT 50 kg, SIZE .5 X 1 X .5 m, POWER .1 kW

POINTING ______ STABILITY ______ DATA 1 MBPS

ORIENTATION Earth CREW: NO. 1 OPERATIONS/DURATION /

SPECIAL GROUND FACILITIES: Ground truth sites

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE .8

9. GROUND TEST OPTION TEST ARTICLE: Prototype SAR preprocessor

TEST DESCRIPTION/REQUIREMENTS: Operate SAR with preprocessor from aircraft at 15-20 km altitude.

SPECIAL GROUND FACILITIES: Aircraft, Ground truth

EXISTING: YES [X] NO [ ]

GROUND TEST LIMITATIONS:

TEST CONFIDENCE

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 76	77	78	79	80		COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS		—							—						
2. DESIGN		—	—						—	—					
3. MFG & C/O			—	—						—	—				
4. TEST & EVAL					—	—						—			
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

Difficulty in handling extremely high data rate causes increased parallelism and cost — PROBABILITY .4

COST RISK $

FT (TDR-2) 7/75

V.B. 6 Onboard Man Interactive Multisensor Recognition Processor

The user input requirements as well as the Outlook for Space project increasing use of earch resources type sensing. The raw data from most these sensor systems produce a tremendous amount of high data rate data which in turn taxes data communications and storage facilities. One approach to coping with the projected data overload is to perform some of the data processing onboard the spacecraft. Spacecraft experiments as related to data processing requirements can be divided into three categories: 1)those for which processing algorithms are known and the characteristics of the data are sufficiently invarient or predictable that automated on board processing is feasible; 2) those for which onboard processing is unfeasible due to the completely unpredictable characteristics of the data or other reasons; 3) those for which processing algorithms are known and sufficient uncertainty exists in the sensor data that successful recognition processing must be accompanied by man supervised training or direction of the processing algorithms. It is this latter category of experiments toward which this flight experiment is directed. Since many of the earth resources experiments fall into this category, a sizeable reduction in the space to ground data handling requirements can be achieved by implementation of such an onboard man-supervised processor.

The technology around which the processor is fabricated greatly affects the implementation of such a system. One approach based on recently-developed ground-based hardware to perform recognition processing of multi-spectral image data is summarized below. The heart of the processing system is a high-speed digital pipeline processor. The pipeline processor is organized such that the basic form of the processing algorithm is hardwired into the pipeline hardware and the detailed implementation of the algorithm is controlled by constants and control parameters fed to the pipeline processor by a man supervised control processor. Determination of the appropriate constants and control functions requires the introduction and correlation of a certain amount of ground truth information. It is the supervision of the ground truth training process and evaluation of the adequacy of previous training to current data conditions which requires the man-machine interaction. One of the chief requirements for a flight experiment of such a processing system is to evaluate the ability of man to perform this task in a real time space environment.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V.B.6
PAGE 1

1. REF. NO. ______ PREP DATE 8/13/75 REV DATE ______ LTR ______
CATEGORY System

2. TITLE On-board Man Interactive Multisensor Recognition Processor

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
4	4	7

The development and flight verification of a high speed data processor to perform recognition processing of earth resources image data in space. This processing system will require the development of flight worthy high speed parellel processing subsystems, High speed buffer storage, Man interactive controls and displays, General purpose control computers, and Optimized control and recognition software.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1983
PAYLOAD DEVELOPMENT LEAD TIME 1 YEARS. TECHNOLOGY NEED DATE 1982

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS 1) Reduction in the end-to-end processing time. 2) Capability of selecting useful data in realtime. 3) Multiple use of sensors. 4) Decreased interaction between experimenter and sensing-processing systems.

POTENTIAL COST BENEFITS On-board recognition processing of earth resources data will greatly reduce the requirements for and therefore cost of data transfer, ground storage and processing facilities.

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS 1) Operation of parallel processors and buffer storage devices at faster than realtime data rates (25 MHe). 2) Training set selection and retraining frequency. 3) Efficiency of man-machine interaction in realtime environment.

REQUIRED SUPPORTING TECHNOLOGIES 1) Higher speed parallel processor technology 2) Higher speed and capacity data storage devices (Disc-like) 3) Man-machine interaction optimization for data processing.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TOR-1) 7/75

TITLE On-board Manned Interactive Multisensor Recognition Processor **NO.** ______

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION **TEST ARTICLE:** Earth resources data processing system

TEST DESCRIPTION: ALT. (max/min) 250 / 170 km, INCL. 57 deg, TIME 16 hr

Data from one or more image sensors will be processed in realtime by the on-board system and transmitted to the ground for comparison.

BENEFIT OF SPACE TEST: Evaluation of efficiency and accuracy of realtime earth resources data processing.

EQUIPMENT: WEIGHT 1000 kg, SIZE 1 X 2 X 1 m, POWER ______ kW

POINTING 1 arc sec. STABILITY ______ DATA ______

ORIENTATION Earth CREW: NO. 1 OPERATIONS/DURATION 25 / @5 hr.

SPECIAL GROUND FACILITIES: Image Data Processing

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE .8

9. GROUND TEST OPTION **TEST ARTICLE:** Prototype earth resources data processing system.

TEST DESCRIPTION/REQUIREMENTS: Simulation of data generation in realtime and evaluation of processing efficiency and accuracy.

SPECIAL GROUND FACILITIES: Development of prototype processor

EXISTING: YES [ ] NO [ ]

GROUND TEST LIMITATIONS: Difficulty of simulating actual data from multiple sensors in realtime.

TEST CONFIDENCE .5

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 78	79	80	81	32	83	COST ($)	GROUND TEST OPTION 78	79	80	81	82	83	COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

High Speed Processing and Man-Machine Interaction

COST RISK $ ______

FT (1DR-2) 7/75

(7) Advanced Teleoperator Vision System

Discussion

The purpose of this flight experiment is to demonstrate advanced facilities for augmenting operator vision in the performance of Shuttle or free-flying teleoperator remote manipulation tasks. Since these facilities are intended to replace those used in the first Shuttle and Payload Systems, their demonstration in space under zero-g conditions and in actual payload deployment or servicing is considered essential before adoption. Testing of the vision system on the ground prior to flight tests will be done in the course of its development; however, the extent to which it truly aids the Payload Specialist in his work can be determined only in repeated use.

The improvements offered in the proposed vision system reflect the addition of processors to the flight equipment that would enable the following functions to be performed in real time:

(1) Enhancement of predetermined or operator-selected features of the images transmitted from the remote TV cameras to emphasize those needed for operator decisions and actions

(2) Bandwidth compression (when appropriate) to improve the amount of useful or high-resolution detail that can be transmitted over the available channel.

(3) Generation of displays based on non-visual information, such as the position of manipulator joints and their relation to other structural elements, to supplement the TV data and give the operator a more complete overview of the worksite

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V.B.7
PAGE 1

1. REF. NO. ______ **PREP DATE** 8/11/75 **REV DATE** ______ **LTR** ______
CATEGORY Software

2. TITLE Advanced Teleoperator Vision System

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
4	5	7

Develop an advanced vision system for teleoperator control of Shuttle payload operations or free-flying teleoperator servicing of deployed payloads. The system should have the following features:

1) Extraction and enhancement of worksite features needed for improved operator perception of task environment.
2) Application of bandwidth compression and scene analysis techniques to increase content of useful information supplied to operator over channel with limited bandwidth (for IUS).
3) Development of simulation of remote effects in task environment to increase operator confidence and efficiency in carrying out task steps.

4. SCHEDULE REQUIREMENTS **FIRST PAYLOAD FLIGHT DATE** 1984
PAYLOAD DEVELOPMENT LEAD TIME 7 **YEARS. TECHNOLOGY NEED DATE** 1980

5. BENEFIT OF ADVANCEMENT **NUMBER OF PAYLOADS** All

TECHNICAL BENEFITS Increase operator efficiency in performing Shuttle and IUS operations and thus increase the number of tasks that can be performed in a given time; also increase probability of successful task performance without accident.

POTENTIAL COST BENEFITS Reduce cost per minute of Shuttle and IUS remote manipulator operations.

ESTIMATED COST SAVINGS $ 25%

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Algorithm and hardware development; software generation (by simulator).

REQUIRED SUPPORTING TECHNOLOGIES TV image processing; on-board computers; scene analysis; source encoding.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR-1) 7/75

TITLE Advanced Teleoperator Vision System

NO.

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION

TEST ARTICLE: Teleoperator Vision System

TEST DESCRIPTION: ALT. (max/min) / km, INCL. deg, TIME hr

BENEFIT OF SPACE TEST: Compare advanced system with system used in first [illegible]le flights

EQUIPMENT: WEIGHT kg, SIZE X X m, POWER kW

POINTING STABILITY DATA

ORIENTATION CREW: NO. OPERATIONS/DURATION /

SPECIAL GROUND FACILITIES: Use ground system to compare performance of earth-based operator with that of Payload Specialist.

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE

9. GROUND TEST OPTION

TEST ARTICLE:

Some ground tests can be made, but zero-g conditions cannot be duplicated.

TEST DESCRIPTION/REQUIREMENTS:

SPECIAL GROUND FACILITIES:

EXISTING: YES ☐ NO ☒

GROUND TEST LIMITATIONS: See above

TEST CONFIDENCE

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ (SUM OF PROGRAM COSTS $)

12. DOMINANT RISK/TECH PROBLEM

COST IMPACT PROBABILITY

COST RISK $

FT (TDR-2) 7/75

(8) Modular Architecture for Data Processing and Transfer System

To date, the approach to onboard data processing and transfer systems has been central location of processor memory, I/O, and software. As requirements have grown, so has the complexity and size of the various system elements. The need for longer life systems has posed an additional problem since system elements are already so complex, fault tolerance and correction cannot easily be accommodated. Most current approaches to this problem result in multiply redundant system elements; elements already large and complex. As requirements on the data processing system have increased, so has the software complexity. Since the software now resides in a single processor memory, this has given rise to problems in software interaction and difficulty with additions and changes when they are required. Sophisticated operating systems and programming languages have become necessary to cope with this burgeoning problem.

With the advent of the microprocessor and other LSI devices, the opportunity now arises to consider the possibility of distributing the functions of the data processing system among the user elements. For example, a processor unit could become a part of a sensor subsystem, along with memory necessary to hold the control software to operate the sensor, to store the data collected, and to preprocess the data. Other processor/memory units could be integrated with T, T&C, Power, Propulsion, and G, N&C systems. Another processor unit may function as a controller for the data bus which would interconnect the network of processors and memories. Once the distributed element and function concept is accepted, many other possibilities emerge. New concepts in fault detection, tolerance, and correction become possible. Reliability and redundancy requirements can be approached differently. The total architecture of the data processing system becomes accessible and adaptable. Missions fly only what they require and as much as they require. Designers are not limited to some already designed system with its predetermined and frequently limited or restrictive capabilities.

It is the intent of this effort to maximize the use of commerically developed devices such as microprocessors, memories, and other LSI devices. The use of such commercial developments will yield significant cost and time savings. Unique LSI circuit developments can be minimized. Support hardware and software compilers, cross-assemblers, and documentation are already available. In addition, there is a potentially large base of experienced designers, programmers and users.

As with other electronic systems of this type, the space environment does not offer any condition that will either cause a modular data processing system to behave differently or uncover any unknown weaknesses. Nonetheless, the extent to which this technology advancement will affect and modify existing techniques and systems may pose a significant question of unproven risk to the project manager. Therefore, a technology demonstration experiment, possibly in parallel with an existing technology, may serve to create confidence in the minds of potential users.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V.B.8
PAGE 1

1. REF. NO. ______ PREP DATE 8/8/75 REV DATE ______ LTR ______
CATEGORY Systems

2. TITLE Modular Architecture For L[illegible]a Processing And Transfer Systems

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
1		7

The basic requirement is that of developing a systems technology using commercially developed microprocessors and other LSI circuits in a modular, distributed architecture concept. The technology will encompass the end-to-end on-board data processing function including hardware and software.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980
PAYLOAD DEVELOPMENT LEAD TIME 2 YEARS. TECHNOLOGY NEED DATE 1978

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS 1) Adaptive system design. 2) Modular hardware. 3) Modular software. 4) Simplified software development. 5) Available support hardware and software. 6) Existing technical base of design and application knowledge

POTENTIAL COST BENEFITS 1) Reduced design costs. 2) Less costly to make changes. 3) Hardware costs cut significantly. 4) Software development costs down. 5) Ground support hardware and software available at minimal cost. Estimated cost reduction of 10:1 per mission. ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS The problem resolves itself into a straight forward design and development task. No risk producing problems are foreseen.

REQUIRED SUPPORTING TECHNOLOGIES Random and mass memories.

7. REFERENCE DOCUMENTS/COMMENTS A Forecast of Space Tech. 3-80-81
RTOP 506-20-11 "Advanced Digital Data System For Deep Space" OAST/JPL

FT (TDR-1) 7/75

TITLE ______ NO. ______

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: ______

TEST DESCRIPTION: ALT. (max/min) ____/____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: ______

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ____ OPERATIONS/DURATION ____/____

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

FT (TDR-2) 7/75

(9) Automation of Ground Support Functions

Description

The purpose of the proposed flight experiment is to demonstrate the successful automation of selected shuttle (and perhaps payload) ground support functions. The benefits would be a savings in cost for all subsequent shuttle flights for which the same functions were required. Since the system to be developed would constitute a different method of conducting certain shuttle operations, a flight experiment in which the accepted and proposed implementations would be compared is considered essential.

The approach is to ascertain those aspects of ground operations which require a low level of human skill and attention, but which presently demand human perceptual or cognitive capabilities, and use advanced software techniques to automate them or to consolidate them so that they could be brought under the control of a reduced number of human operators.

Preparation for the experiment entails the following steps:

1. Conducting a study of proposed shuttle operational procedures and staffing plans. This work should be done jointly by operations planners and by software experts familiar with the status of research in the following areas:

   a. human-machine communication in natural language
   b. speech recognition and speech synthesis
   c. problem-solving and planning
   d. process-control systems
   e. pattern recognition and scene analysis
   f. computer-aided instruction
   g. data-base management

2. Selecting a number of aspects of flight control that lend themselves to automation or consolidation.

3. Adapting existing software capabilities to the flight requirements and to a flight-operations environment for the selected functions, and providing a reliable and economical implementation.
4. Testing the system during actual shuttle flights, but with it uncoupled from the shuttle system.
5. Installing the system so that it can be placed in control during portions of an actual flight for piecewise comparison with the accepted system.

C. 2

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V.B.9
PAGE 1

1. REF. NO. 2A4 PREP DATE 8/9/75 REV DATE ______ LTR ____
CATEGORY Software

2. TITLE Automation Of Ground Support Functions

3. TECHNOLOGY ADVANCEMENT REQUIRED

Reduce the level of human effort required in support of flight operations.

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
1	1	2

Lowering of costs by a factor of two is a desired target.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1982
PAYLOAD DEVELOPMENT LEAD TIME 2 YEARS. TECHNOLOGY NEED DATE 1979

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 1 or more

TECHNICAL BENEFITS Increased efficiency and speed of response in selected ground support functions.

POTENTIAL COST BENEFITS 50% reduction in ground support costs.

ESTIMATED COST SAVINGS $ Unknown

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Finding efficient and economical software implementations. In some cases, automation may require advances in the state of the art.

REQUIRED SUPPORTING TECHNOLOGIES Computer and information science; human factors; communication technology.

7. REFERENCE DOCUMENTS/COMMENTS

RTOP 310-40-36 Automatic Data Handling OTDA-GSFC

FT (TDR-1) 7/75

TITLE Automation Of Ground Support Functions NO. ____

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Mission support procedures and costs

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Demonstrate cost benefits of automated procedures

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: Selected data processing equipment and programs

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: Present mission support procedures and costs.

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☒ NO ☐

GROUND TEST LIMITATIONS: ____

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

F 1 (TDR 2) 7/75

(10) Radiation Tolerant Electronic Components and Subsystems

There currently are a number of semiconductor technologies in existence, or under development, and numerous variations within each type. Each has certain characteristics which make it more or less suited to use in spacecraft subsystems. Some of these, such as speed, power, voltage level, density, difficulty in manufacture, cost, and reliability, are well known or can be determined through ground investigation and testing. One characteristic though has not received sufficient investigation and testing, namely, the semiconductor's tolerance to high energy, long duration space radiation. Such conditions are found in the earth's Van Allen belts, at geosychronous altitudes, during interplanetary transit and in the Van Allen belts of other planets.

It is possible to perform limited investigations of these phenomena in the laboratory using radiation sources and large particle accelerators. High energy particles can be obtained for short periods of time and the results extrapolated for projected mission times up to 5 years, but actual testing of long term effects is not possible due to technical difficulties and high cost.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V. B. 10
PAGE 1

1. **REF. NO.** 3A2 **PREP DATE** 8/8/75 **REV DATE** ______ **LTR** ______
CATEGORY Systems

2. **TITLE** Radiation Tolerant Electronic Components And Subsystems

3. **TECHNOLOGY ADVANCEMENT REQUIRED**

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
5	5	7

A determination and demonstration of the most suitable semiconductor technology(s) for use in component development for spacecraft subsystems where the exposure environment includes high energy radiation and particles over long periods of time.

4. **SCHEDULE REQUIREMENTS** **FIRST PAYLOAD FLIGHT DATE** 1980
PAYLOAD DEVELOPMENT LEAD TIME 2 **YEARS. TECHNOLOGY NEED DATE** 1978

5. **BENEFIT OF ADVANCEMENT** **NUMBER OF PAYLOADS** ______

TECHNICAL BENEFITS Improved and assured performance of spacecraft and payloads where the mission involves exposure to the high energy radiation and particles over long periods of time.

POTENTIAL COST BENEFITS Reduction in subsystem cost by a factor of 2-3 by the reduction of redundancy. Additional savings in power and weight will result in further cost reductions.

ESTIMATED COST SAVINGS $ ______

6. **RISK IN TECHNOLOGY ADVANCEMENT**

TECHNICAL PROBLEMS The development of test support equipment either not susceptible to the radiation environment or whose effect can be measured and removed. A possible alternative could be the use of a passive or semi-passive spacecraft to be recovered by shuttle after approximately 3 years.

REQUIRED SUPPORTING TECHNOLOGIES Further development of the newer CMOS and I^2L technologies into useful components for spacecraft testing.

7. **REFERENCE DOCUMENTS/COMMENTS** Fundamental Requirement for High Reliability Systems for Deep Space Operation

FT (TDR-1) 7/75

TITLE Radiation Tolerant Electronic Components And Subsystems NO. ______
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Processor modules, memories, interfaces, related and other discrete components in appropriate packaging configurations.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr
Test article should be placed in an orbit to receive the maximum continuous dosage from the Van Allen belts. Use of Shuttle-IUS is anticipated.

BENEFIT OF SPACE TEST: Exposure of the test articles to a prolonged environment of high energy radiation and particles.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW
POINTING ____ STABILITY ____ DATA ____
ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____
SPECIAL GROUND FACILITIES: ____
EXISTING: YES ☐ NO ☐
TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: Same

TEST DESCRIPTION/REQUIREMENTS: Test articles need to be placed in a facility where they can receive a high level, continuous dosage of high energy radiation and particles.

SPECIAL GROUND FACILITIES: Laboratory containing radiation sources and large particle accelerators capable of operation over extended periods of time approaching years.
EXISTING: YES ☐ NO ☒

GROUND TEST LIMITATIONS: ____
TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FT (TDR-2) 7/75

(11) Demonstration of Space Power Transfer by Microwaves

A synchronous satellite has been proposed which would gather and transfer to earth five gigawatts of solar power. The proposed transfer medium is S-Band microwaves. This would require high power (5 kw), high efficiency (90%) tubes, an antenna with greater than 90 db gain at 90% efficiency, and a phase control system capable of pointing the antenna to within 0.005 degrees. It has been estimated that the unknowns in this microwave power transfer are as significant as those in the entire Apollo Program. Therefore, a series of experiments in space are required which will establish solutions to technology problems at stages from component to system level.

Specifically, tubes of a no-envelope, cold-cathode type are required. Concerns are efficiency, cathode start-up, and long-term cathode contamination. The antenna probably will be a planar array of slotted wave guides. These cannot be carried to space intact, but must be segmented. Space assembly is a concern, as well as the ability to control flatness. The phase control system has the basic problem of maintaining a phase reference across the entire array and driving the individual elements in the proper relative phases in order to form and direct a pencil-beam.

The series of proposed experiments should demonstrate the individual components, such as tubes, operating with Spacelab-Pallet, and lead up to a final test of an antenna system of about 125,000 square feet. These experiments must be coupled with flights demonstrating the other aspects of the program such as solar cells and primary structure. An estimated total of fifty Shuttle flights will be required to completely flight-demonstrate the total concept.

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. V. B. 11
PAGE 1

1. REF. NO. ________ PREP DATE ________ REV DATE ________ LTR ____
CATEGORY ________

2. TITLE Demonstration Of Transfer Of Space Power To Earth By Microwaves

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

High efficiency tube/high gain antenna integrated system capable of transferring 5 Gw of power to earth via microwaves. Specifically, 5 KW, 90% efficiency tubes will be integrated with a phased array antenna with 90% efficiency and gain in excess of 70 db to radiate microwave power to a ground rectenna. This flight experiment will require precursor orbital tests to demonstrate the individual tubes, antenna elements, and phase control. A number of Shuttle launches will be required to deliver components to orbit, and on-orbit assembly will be required. As many as 50 shuttle flights will be required through 1985.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1981
PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1983

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ________

TECHNICAL BENEFITS Key element in development of space solar power as a new terrestrial energy source. Provides critical information for a mid-80's national commitment to space power.

POTENTIAL COST BENEFITS Multiple billions of dollars out of the estimated 50 billion dollars required to provide the first operational power satellite in 1995.

ESTIMATED COST SAVINGS $ ________

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Attainment of acceptable efficiency tubes/antennas, phase control, and reliability.

REQUIRED SUPPORTING TECHNOLOGIES Space processing and orbital assembly.

7. REFERENCE DOCUMENTS/COMMENTS Outlook for Space, OMSF user input.

FT (TDR-1) 7/75

TITLE ______ NO. ______
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Integrated system consisting of 1) Five KW, no. envelope tube; 2) Planar array antenna; 3) Phase Control

TEST DESCRIPTION: ALT. (max/min) 500 / 250 km, INCL. 32° deg, TIME ______ hr

Demonstrate microwave power transmission and reliability

BENEFIT OF SPACE TEST: Essential to demonstration of open tubes and phase control in a flexible structure

EQUIPMENT: WEIGHT ______ kg, SIZE ______ X ______ X ______ m, POWER ______ kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: Rectenna elements distributed properly in order to sample beam distribution.

EXISTING: YES ☐ NO ☒

TEST CONFIDENCE .95

9. GROUND TEST OPTION TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: Certain elements of the program, such as static phase control, could be demonstrated. However, open tubes and dynamic structure/phase interaction could not.

TEST CONFIDENCE 30%

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 74	80	81	82	83	84	COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS	----	--X													
2. DESIGN		X-	----	-X											
3. MFG & C/O				X-	-----	-X									
4. TEST & EVAL						X--	--X								
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

Open microwave tubes

High efficiency phased array antenna

COST RISK $ ______

FT (TDR 2) 7/75

VI. CONCLUSIONS AND RECOMMENDATIONS

The product generated by the Data Processing and Transfer Study Group is the identification of technology requirements (Table IV-1) and flight experiments (Table V-1) which will meet the user community (OA: OMSF: OSS & OTDA) needs and those suggested in the report of the Outlook for Space study.

The technologies and flight experiments in need of development fall into 12 groups: (1A) High Data Rate Processing; (1B) Information Extraction & Data Compression; (1C) Wideband Information Transfer; (1D) High Density, Low Cost Storage; (1E) Modular Architecture; (1F) Manned Interaction; (1G) Communications; (2A) Software; (2B) Electronic & Modular Structure; (2C) End-to-End and (GST) General Supporting Technology. The needed technologies and flight experiments generally serve two major thrusts.

(1) 1000:1 increase in end-to-end information handling

(2) Life-cycle cost reduction of 10:1

Extensive technology development is in progress as shown by Table VI-1. These efforts, and the technological advances advocated by this study group, affect a broad spectrum of candidate objectives for future space activities. These developments will not only demonstrate feasibility and economic viability of quite complex missions and systems but significantly reduce the cost of accomplishing many specific objectives in space.

TABLE VI-1

DATA PROCESSING & TRANSFER TECHNOLOGY (Ongoing)

Legend	Technology Description	RTOP
1A4	Data Handling & Processing Techniques	310-40-25
1A5	Computational Req. Def. for Data Handling & Processing	310-40-38
1A6	Information Processing, Analysis & Display	656-42-01
1A7	Parallel Image Processing	506-20-14
1A8	Hybrid Digital/Optical Processing Technology	656-23-01
1A9	Optical-Digital Processing of Multi-Spectral Data	177-32-81
1A10	Automatic Data Handling Tech. Dev.	310-40-36
1B2	Data Compacking Technology	175-31-42
1B3	Data Compression & Error Protection	177-25-41
1B4	Data Handling & Processing Techniques	656-11-02
1B5	Conceptual Design of Compression/Reconstruction Hardware/Software System	656-xx
1B6	Video Compression Technology Dev. & Demo.	650-60-10
1C5	Outer Planet Probe Telecomm.	186-68-75
1C6	Microwave Power Amplifier & Low Noise Preamplifier	506-20-24
1C7	High Data Rate Transfer & Tracking	506-20-32
1C8	Data Link Tech. Development, 20-200 GHZ 200-1000 GHZ	650-60-11
1C9	Far In IR Masers	650-60-12
1C10	Tracking & Data Relay Systems Development	310-20-20
1C11	Ground Station Antenna for Wideband Transmissions	210-20-31
1C12	Control System Development for Large Tracking Antennas	310-20-32

1C13	Development of S & K Band Spacecraft Antenna Transponder, Transmitter, & Receivers	310-20-46
1C14	Micro-min S/X Band Transducer Development	506-20-21
1C15	Data Link Technology	
1C16	Antenna Research	650-10-10
1C17	Progation Research	650-60-13
1C18	Standard Spacecraft Transponder	
1C19	Antenna Systems Development	310-20-65
1C20	Radio Systems Development	310-20-66
1D5	High Density Magnetic Tape Recorder Dev.	656-11-03
1D6	Specifications of an Int. Std. Ref. Mag. Tape System	310-40-44
1D7	Solid State Data Recorder	570-71-01
1D8	Electron Devices & Components	506-18-21
1D9	High Capacity Data Systems	506-20-13
2A16	Data Management System Planning	656-11-01
2A17	Image Processing Facility Performance Evaluation & Improvement Definition	310-40-39
2A18	Project Operations Control Center Computational System for the 1980's	310-40-40
2A19	Computer Operating Systems Study	310-40-41
2A20	Procedures for Definition & Implementation of Data Systems Requirements	656-11-04
2A21	Data Processing Technique Assessment & Concept Def. Systems Analysis etc.q	656-12-01
2A22	Data Formatting - Processing	656-21-01
2A23	Development of Practices & Techniques of Hi-Speed Data Systems	656-22-01

2A24	Advanced Methods for Data Base Management	656-31-01
2A25	Data Management	656-xx
2A26	Conceptual Math. Models for Processing, Display & Management of Large Data Bases	177-32-71
2A27	Research Leading to the Development of an Useful Earth Observation Data Management System	656-11-01